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The Cova des Pas de Vallgornera (Llucmajor, Mallorca): a singular deposit bearing an exceptional well preserved Early Pleistocene vertebrate fauna

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Abstract: The Cova des Pas de Vallgornera is the longest cave of Mallorca (Balearic Islands, Western Mediterranean) and one of the 30 longest caves in the world. The exploration of one of the galleries allowed the discovery of a fossiliferous deposit of vertebrate remains in a remarkable preservation state. The fossil faunal complex found in this gallery is composed of up to 5 mammalian species (*Myotragus* aff. *kopperi*, *Hypnomys onicensis*, *Nesiotites* aff. *ponsi*, *Rhinolophus* aff. *mehelyi* and *Pipistrellus* sp.), at least 14 bird species (among them two Mallorcan endemic taxa: *Pica mourerae* and *Athene vallgornerensis*), one reptile (*Podarcis* aff. *lifordi*) and one amphibian (*Discoglossus* sp.). This faunal composition is similar to the one recorded in the Pedrera de s'Ònix, a well known deposit from the Early Pleistocene of Mallorca, and shared morphological characteristics between taxa of both deposits suggest that the chronology of the Cova des Pas de Vallgornera should be considered Early Pleistocene as well. Both taxonomical analysis and chronology of this fauna furnished information on some speleological aspects of the cave.

Keywords: paleontological deposit; Early Pleistocene; Cova des Pas de Vallgornera; Mallorca; fossil vertebrates

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INTRODUCTION

The Balearic Islands are an archipelago located at the western area of the Mediterranean Sea (Fig. 1 A-B). It is compound of two different groups of islands. The Western set, or Pityusic Islands, consists of two main islands (Eivissa ["Ibiza"] and Formentera). On the other hand the Eastern set, or Gymnesic Islands, is more isolated than the Pityusics and constitutes of two main islands (Mallorca and Menorca). The current isolation of the Balearic Islands began at the end of the Messinian Salinity Crisis (MSC), 5.35 My ago (Gautier et al., 1994; Clauzon et al., 1996; Krijgsman et al., 1999).

The existence of abundant caves all around Mallorca is favoured by the geological characteristics

of the island, mainly composed of limestones. More than 2,000 caves have been explored and surveyed in the island (Encinas, 2006). Exploration and paleontological excavation in some of these Balearic caves have allowed the discovery and subsequent study and analysis of the fossil fauna from these islands.

Different faunal assemblages have been identified in Mallorca, but the most relevant insular fauna has been recorded in post-Messinian deposits (e.g., Alcover et al., 1981). This faunal assemblage (called *Myotragus*-fauna) is mainly composed of an artiodactyl, *Myotragus* (Bovidae) (Bate, 1909), a rodent, *Hypnomys* (Gliridae) (Bate, 1918) and an insectivore, *Nesiotites* (Soricidae) (Bate, 1944). Although these three taxa survived during

all the Plio-Pleistocene, recent discoveries prove that other mammalian species colonized Mallorca during the Messinian, and that they became extinct during the Pliocene and Early Pleistocene (Bover et al., 2014, and references therein).

In 1968, a cave known since then as Cova des Pas de Vallgornera, and located on the southern coast of Mallorca, at the municipality of Llucmajor, was discovered in the course of a drilling carried out for the construction of a cesspit.

After the initial exploration of the cave (Collignon, 1982), a first detailed topographic survey published by Merino (1993) represents a cave with a total length of approximately 2 km. After the negotiation of two narrow passages in 1994 and 2004, the length of the cave has been remarkably increased reaching 6.5 km in 2000 (Merino, 2000), 23 km in 2006 (Merino et al., 2006), 40 km in 2007 (Merino et al., 2007), 56 km in 2008 (Merino et al., 2008), 62 km in 2009 (Gràcia et al., 2009; Merino et al., 2009) and 65 km in 2011 (Merino et al., 2011). Currently, more than 74 km have been already surveyed (Merino et al., 2014) and it is considered one of the 30 longest caves in the world (Fig. 1 C). Currently, this cave is only accessible through the artificial entrance excavated in 1968.

The Cova des Pas de Vallgornera (from now on CPV) is an extensive maze cave partially drowned by brackish phreatic waters and it lies in a tabular platform built up by an Upper Miocene reefal limestone sequence (Ginés et al., 2008; Fornós et al., 2010a, 2011, and references there in). It has emerged as a conspicuous

coastal cave-system that allows to investigate complex speleogenetic mechanisms and speleothem formation processes, many of them controlled by Quaternary sea level changes (e.g., Ginés et al., 2009a, 2009b; Merino et al., 2009; Tuccimei et al., 2009; Dorale et al., 2010; Fornós et al., 2010a, 2011; Merino & Fornós, 2010). In this paper we present the fossil faunal assemblage that has been recorded through a single excavation campaign carried out during May 2010 at CPV. The bones collected in the fossiliferous deposit provided relevant information on the collapse of the ancient natural entrance. Additionally, faunal remains also shed light on some other aspects on the geomorphological history of the cave and its chronology.

METHODS

The short time available for the excavation of the deposit and the complexity of the whole excavation in such a remote place of the cave precluded the use of grid squares to locate the bones in the deposit. Additionally, the main objective of the excavation was to remove the material from the surface, a rescue of material for its conservation and scientific study. Therefore, the collected material was reported on a detailed topographical survey of the passage based on landmarks of the topography and each collected item has been referred to its proximity to one of the 28 established sections (Fig. 1 D, T1-T28). The excavation was mainly collecting bones by hand, although the material partially covered by flowstone had to be

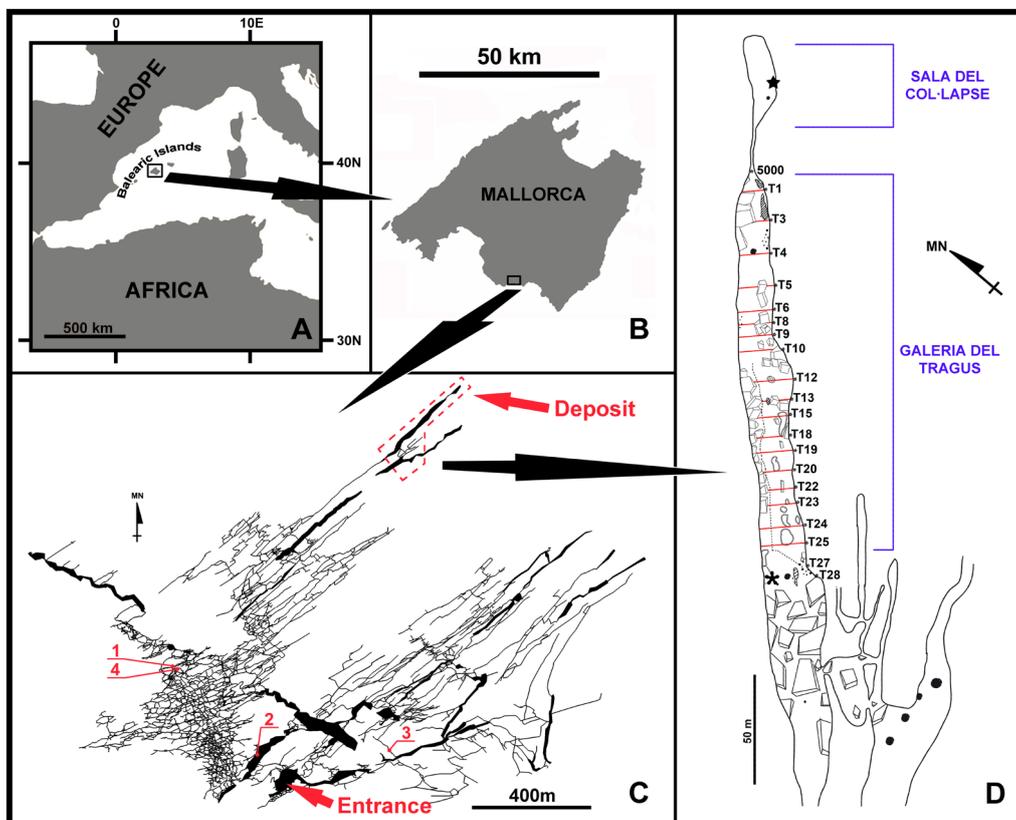


Fig. 1. Map of the Western Mediterranean, with A: the location of the Balearic Islands, and, B: the location of CPV in the island of Mallorca. C: Schematic topographic survey of CPV, indicating the presence of complete/articulated skeletons of fossil vertebrates mentioned in the text (1. *Myotragus*, 2-4. *Hypnomys* sp.), and the location of the current entrance to the cave and the deposit. D: Detailed topographic survey of the Galeria del Tragus/Sala del Col-lapse. Topography landmarks (5000, and location of section T1 to T28) were used to locate the fossil material in the deposit. Asterisk close to T28 indicates the location of the two associated skeletons of *Myotragus* juveniles, whereas the star in the Sala del Col-lapse indicates the location of the articulated *Myotragus* skeleton (IMEDEA 103003).

removed using mechanical techniques (Fig. 2.A). After labelling and packaging, the materials were placed in protected containers and carried outside the cave once every day by volunteers. All bones were initially cleaned with water without any kind of aggressive mechanical tool or chemical treatment. A professional conservator (Mr Bernat Font, St Llorenç, Mallorca) worked on a selection of bones that were embedded in hard sediment and/or flowstone, or fragmented. The cleaning of bones was done basically through a mechanical work, although when necessary it was done through a chemically controlled process (see Diaz et al., 2014).

The material from CPV and from other deposits used in this paper as comparison material is listed in Annex 1 (<http://dx.doi.org/10.5038/1827-806X.43.2.6>). See Diaz et al. (2014) for a complete list of the obtained bones from CPV during the excavation.

The nomenclature used for the teeth is as follows: lowercase letters ('m' for molar, 'p' for premolar, and 'i' for incisor) for lower teeth, and uppercase letters ('M', 'P') for upper teeth. The number after the letter is the position that the tooth occupies in the mandible or maxilla.

Measurements of bones have been taken with a digital caliper (0.02 mm accuracy). Metric values for the *Nesiotites* bones were recorded using a stereomicroscope (Olympus MSZH, objective 64x) connected to a video camera. We followed Reumer (1984) for measurements, with some additions from Rabeder (1972). For the morphometric analysis we used the PAST v2.01 statistical programme (Hammer et al., 2001).

Measurements abbreviations are as follows: H: mandible height; HC: condyle height; Hi: height of i1; Hm1: height of mandibular ramus under m1, in medial view; Hm2: height of mandibular ramus under m2, in medial view; L: length of the jaw measured from P point to the mental foramen; Li: length of i1; Lm1: length of m1; Lm3: length of m1; Lm1-m3: m1-m3 length; Lp3: length of p3; Lp4: length of p4; Ltr: length of lower toothrow; LLF: length of the lower facet of the condyle; LUF: length of the upper facet of the condyle; TAWm1: width of m1 talonid; TRWm1: width of m1 trigonid; WC: condyle width; Wm3: width of m3; Wp4: width of p4.

In the case of the bovid *Myotragus*, as the teeth measurements can be influenced by the wear pattern, the measurements were taken at the base of the teeth, but also at 1 cm from the base to be compared with published data (see text and figure captions for further explanation).

Other used abbreviations: CPV: Cova des Pas de Vallgornera; IMEDEA: Institut Mediterrani d'Estudis Avançats (CSIC-UIB); FBE: Federació Balear d'Espeleologia (Balearic Federation of Speleology); ACAD: Australian Centre for Ancient DNA; MNIB-SHNB: Museu de la Naturalesa de les Illes Balears - Societat d'Història Natural de les Balears.

SITE DESCRIPTION

Geological background

The cave is located at the southern coast of Mallorca, a region called Migjorn. Upper Miocene

tabular deposits outcrop all along the southern and eastern coast, shaping this flat karst region (Fornós & Gelabert, 2004). This region must be considered as a post-orogenic carbonate platform that discordantly onlaps the folded Mesozoic basement (Serres de Llevant and Serres Centrals). From a sedimentological point of view, the Upper Miocene deposits constitute a complex reef sequence related to the well-differentiated depositional environments characteristics of tropical carbonate platforms, with a wide textural variability as a function of the reef architecture related to the sea level oscillations and the resulting depositional environments (Pomar et al., 1996). This sedimentological complexity produces sharp lateral and vertical changes of rock facies, which have clear repercussions on the pattern and morphology of the cave. Three main units can be distinguished within the Upper Miocene deposits following Fornós et al. (2002): the basal one known as calcisiltites with *Heterostegina* unit (lower Tortonian in age), the reef complex whose age is Upper Tortonian-Lower Messinian and finally, the Santanyí limestones (also called Terminal Complex) corresponding to the Messinian. CPV is fully developed in the carbonate rocks appertaining to the reef complex (Fornós et al., 2002) being possible to observe, throughout the morphology of its chambers and galleries, the different facies that can be individualised within this unit (Ginés et al., 2008, 2009b, 2014).

Deposit

CPV is an extensive maze cave whose development surpasses 74 km of passages and chambers disposed in two principal tiers regarding its elevation (Merino et al., 2011). The main fossiliferous deposit is located at the end of the northernmost passage called Galeria del Tragus with a length of nearly 300 m, mean width of 10 m and height of 10 m (see Fig. 1 D), which is situated in the Sector Descobriments 2004 (Merino et al., 2006). The rectilinear passage hosting the paleontological deposit runs in southwest-northeast direction and in its first 230 meters it is a wide and high gallery with blocks. At the beginning and end of this part of the gallery important and massive flowstone and speleothems deposits can be observed. A final chamber, the Sala del Col·lapse (Collapse Hall), accessed through a narrow passage, displays a huge collapse of blocks sealing the alleged former entrance from where the different fossil species recorded in the cave entered.

The presence of a flood paleolevel at +4-5 meters on the wall of the Galeria del Tragus suggests the presence of an ancient water-table drowning this part of the cave, which may have conditioned the emplacement of the fossiliferous deposit.

The fossil material was found mainly on surface and widely spread all over the Galeria del Tragus/Sala del Col·lapse (Fig. 2 B). Almost all the bones were in extremely good preservation state, but the bones located in parts of the cave close to walls and speleothemes were partially covered by flowstone.

In the floor of Galeria del Tragus, some naturally produced pits reaching the current water-table



Fig. 2. Excavation of the Galeria del Tragus at CPV. A: Moment of extraction of a bone covered by flowstone. B: Detail of some *Myotragus* bones in the surface of the deposit. Note that some of them were covered by flowstone. C: Partial skeleton of a juvenile of *Myotragus* found at the deposit (Photos: M.A. Perelló).

allowed to study the stratigraphy of this zone, and the differences in faunal composition among different layers were analysed (Fornós et al., 2010b).

Excavation remarks

The fossiliferous deposit is reached after 4 hours of underground trip (including crawling and nearly 1 hour of swimming) from the sole current artificial entrance to the cave (a 6 m deep man-drilled well). At least two very narrow passages must be negotiated precluding the possibility to carry and use large or heavy equipment in the excavation.

The cave is currently under the protection of Government of the Balearic Islands, and was declared Site of Community Importance, within the Natura 2000 Network by the European Union (European Council Directive 92/43/CEE). The access to the cave is highly restricted and a permit for any research task in the cave must be requested. Moreover, some parts of the cave are specially protected for geological or speleological reasons. The transit across these particular spots is extremely restricted. For this reason, the way to reach the deposit was cautiously selected by the explorers from the FBE to avoid passing through these areas. One of these specially protected sectors, a narrow passage just prior to the Galeria del Tragus with fragile pool crystallizations, was unavoidable. Members of the FBE built a small bridge some weeks prior to excavation, to prevent damaging these formations.

The special protection of the cave and the tough efforts (both physical and in logistics) to reach the deposit forced the excavation team to realize all the work in a single campaign of three days spent inside the cave (28th-30th May 2010).

Stratigraphy

Fourteen sediment samples were collected in three stratigraphic sections located at the end of the Galeria del Tragus (Fornós et al., 2010b). Sedimentological characteristics were analyzed and stratigraphical data were also recorded.

Sediments sequence in Galeria del Tragus has a thickness of 2.5 m approximately, but it displays small lateral variations. A complete study of the cave sediments is presented in this volume (Fornós et al., 2014), but it is worth mentioning here that, in general, the sediment sequence observed at the Galeria del Tragus is formed by sands and mud-silts which can be considered allochthonous (entrance facies). This characteristic seems to corroborate the existence of an ancient cave entrance through which sand deposits first, and then sediments infiltrated by surface runoff, entered the cave until the likely closing of it after the collapse of this former entry. The absence of clear lamination and flow structures in the sand deposits of aeolian origin suggest a ramp-type deposition favored by gravity. Nevertheless, the sub-horizontal location of these deposits some hundreds of meters along the gallery seems to indicate a deposition of the whole stratigraphic set in a low dynamic aquatic environment.

The studied sediments sequence shows an evident change in environmental conditions from an arid and probably cold period (prevalence of sands with aeolian origin) to a more humid and probably warm one, during which the increasing of rainfall would have favoured the entry of allochthonous material through surface runoff (Fornós et al., 2010b).

The simplicity of the sequence and the homogeneity of the units seem to indicate that their deposition was produced during a short period of time. This statement is in agreement with the lack of remarkable differences among the fossil remains obtained from the different stratigraphical units.

Chronological remarks

The chronology of the base of the Quaternary was updated and ratified in 2010 by the International Union of Geological Sciences changing its age from 1.8 My to 2.58 My (Gibbard et al., 2010). In this paper we use the proposed nomenclature according to this updated chronology, mainly for the chronological differentiation of “Late Pliocene” (Piacenzian) and “Early Pleistocene” (Gelasian-Calabrian) ranges.

PALEOFAUNAL OVERVIEW

As a complete analysis of the Pliocene and Pleistocene fauna from the Balearic Islands is beyond the main purpose of the present paper, we will focus on the paleofaunal overview of the island where CPV is located, Mallorca. Further information on the whole fossil faunal framework of the Balearic Islands can be found in Bover et al. (2014) and references therein. The fossil faunal assemblage of the last 5.35 My of the Balearic Islands is composed of the so-called *Myotragus*-fauna in Mallorca and the Menorcan Pleistocene and by the *Nuralagus*-fauna in the Menorcan Pliocene (Bover et al., 2008, 2014). In Mallorca, three genera of mammals and a reptile of the original stock that arrived to the island during the Messinian Salinity Crisis (MSC) survived until the Holocene: *Myotragus* (Bovidae, Cetartiodactyla), *Hypnomys* (Gliridae, Rodentia), *Nesiotites* (Soricidae,

Eulipotyphla), and *Podarcis* (Lacertidae, Squamata), while a *Vipera* survived at least until the Late Pliocene. Other terrestrial vertebrates recorded so far in two Mallorcan Early Pliocene deposits, Caló den Rafelino and Na Burguesa-1, i.e., up to three mammals (a leporid, a cricetid, and a murid), up to eight reptiles (a viperid, a colubrid, a scindid, an anguid, a large lacertid, a gekkonid, a scolecophidian, and a tortoise) (Bailon et al., 2010, 2014; Bover et al., 2007, 2010a, 2014; Quintana et al., 2010; Agustí et al., 2012), have not been recorded in fossil deposits with a post-Early Pliocene chronology of Mallorca.

The preliminary analysis of two *Myotragus* mandibles from CPV collected in 2009 allowed corroborating the importance of the deposit and establishing a Late Pliocene/Early Pleistocene chronology for the deposit. For this reason, the comparative analysis of the different taxa found in the cave will be focused on the species and fossil material already available from this epoch in Mallorca. Nevertheless, in this section, a general and short overview of the phylogenetic lineages or taxonomic groups present in the Pliocene, Pleistocene and Holocene Mallorcan deposits will be furnished.

Myotragus

Up to six chronospecies of *Myotragus* have been identified in Mallorca: *M. palomboi* from the earlier Early Pliocene (Bover et al., 2010a), *M. pepgonellae* from the Early-Late Pliocene (Moyà-Solà & Pons-Moyà, 1982), *M. antiquus* from the Late Pliocene (Pons-Moyà, 1977), *M. kopperi* from Early Pleistocene (Moyà-Solà & Pons-Moyà, 1981), *M. batei* from Early-Middle Pleistocene (Crusafont & Angel, 1966), and *M. balearicus* from the Late Pleistocene to Holocene (Bate, 1909).

Some evolutionary changes in the *Myotragus* lineage have been identified, such as a decrease in body size (through an increase of limb bone robustness and a decrease of bone length, especially in metapodials and stylopodium elements), a progressive reduction of number and size of incisiform and premolar teeth, and the reduction of brain size and sense organs (e.g., Alcover et al., 1981; Köhler & Moyà-Solà, 2004; Bover & Tolosa, 2005). Changes in the longevity have been reported in the most recent species, *M. balearicus* (Köhler & Moyà-Solà, 2009; Jordana & Köhler, 2011).

Hypnomys

Regarding *Hypnomys*, although remains of this rodent have been obtained from deposits with Early Pliocene chronology (Alcover et al., 1981; Bover et al., 2014) the oldest formally described species is *H. waldreni*, from Late Pliocene deposits (Reumer, 1979). *H. onicensis*, initially described as *H. intermedius* (Reumer, 1981, 1994), from the Early Pleistocene, has been exclusively found in the Mallorcan deposit of Pedrera de s'Ònix (Manacor). The most recent species, *H. morpheus*, described by Bate (1918), has been recorded in the Middle Pleistocene to Holocene from Mallorca and Menorca.

The most remarkable evolutionary pattern of the lineage is the body size increase and differences among species are mainly related to this characteristic. Another evolutionary trend is the proportional

increase of the zygopodium length (Alcover et al., 1981; Bover et al., 2010b).

Nesiotites

In Mallorca, the shrew genus *Nesiotites* is represented by three described species, *N. rafelinensis* (earliest Early Pliocene, Rofes et al., 2012, but see also Furió & Pons-Monjo, 2013 and Rofes et al., 2013), *N. ponsi* (Late Pliocene, Reumer, 1979) and *N. hidalgo* (Middle Pleistocene to Holocene; Bate, 1944). Additionally, Reumer (1981) described an intermediate form between the last two Mallorcan species, identifying it as *N. ex. interc. ponsi-hidalgo* (or *N. aff. ponsi*, according to Alcover et al., 1981), in the Early Pleistocene deposit of Pedrera de s'Ònix (Manacor). This intermediate form from Pedrera de s'Ònix has been reported as indistinguishable from *N. meloussae* (Pons-Monjo et al., 2010, 2012), a species initially described from the Early Pleistocene of Menorca (Pons-Moyà & Moyà-Solà, 1980), although this identity remains unclear (e.g., it is not considered by Furió & Pons-Monjo, 2013).

Evolutionary trends of the genus include the size increase and the loss of the upper fourth unicuspid (in variable proportion of absence of this tooth in Late Pleistocene and Holocene populations; e.g., Reumer, 1980; Alcover et al., 1981; Pons-Monjo et al., 2012; Rofes et al., 2012).

Herpetofauna

As happens with the fossil mammals, although several endemic species of reptiles and amphibians have been recorded from the Mallorcan Early Pliocene (Bover et al., 2007, 2014; Bailon et al., 2010) belonging to the faunal stock that reached the island during the MSC, just one reptile, *Podarcis lilfordi* (Lacertidae, Squamata) and one amphibian, *Alytes muletensis* (Discoglossidae, Anura), survived until Late Pleistocene/Holocene. Both *P. lilfordi* and *A. muletensis* are still currently living in some Mallorcan localities. A *Discoglossus* (Discoglossidae, Anura) has been also recorded in the Early Pleistocene deposit of Pedrera de s'Ònix, and a *Vipera* (Viperidae, Squamata) was present at the Late Pliocene.

Birds

The current knowledge of fossil bird fauna from the Early Pliocene of Mallorca comes from the site of Pedrera de s'Ònix (Mourer-Chauviré et al., 1977, 1980; Alcover et al., 1981; Sondaar et al., 1995; Seguí, 2001). Twenty-seven taxa have been reported at this site, including *Tyto balearica*, *Aegypius cf. monachus*, *Pica mourerae*, and *Corvus pliocenensis*. A mixture of species linked to fresh-water masses and woodlands characterizes this fauna. The Late Pleistocene bird fauna from Mallorca known so far practically not includes species linked to fresh-water masses.

SYSTEMATIC PALEONTOLOGY

Amphibians

Three bones (fragmented urostyle, humerus and tibiofibula) belonging to *Discoglossus* sp.

(Discoglossidae, Anura) are the sole evidence for the presence of amphibians in the cave. Their morphology fits well with an undescribed species that previously was only known in Mallorca from Pedrera de s'Ònix, where it is relatively abundant (Alcover et al., 1981).

Reptiles

A small lizard has been also recorded in CPV through 12 bones (femora, humeri, jaws, and maxillae), representing at least 4 individuals, two adults and two juveniles. We attribute them to *Podarcis* aff. *lilfordi* (Lacertidae, Squamata). All bones are more gracile than in recent *Podarcis lilfordi*, and agree in size to the lizard present in Pedrera de s'Ònix (Kotsakis, 1981). A complete recovered jaw has 17 teeth, but alveoli for 5 more teeth can be observed.

Birds

Birds are slightly more abundant in CPV than amphibians and reptiles. Twenty-eight bones have been obtained, belonging to at least 14 species (see Table 1, Fig. 3). A fossil Little Owl has been described from this cave on the basis of two bones (Guerra et al., 2012), including a highly diagnostic tarsometatarsus: *Athene vullgornerensis*. It has the shortest tarsometatarsus among all the extant and extinct species from its genus in the Western Palearctic. Its shape resembles the *Athene angelis* tarsometatarsus, although it is markedly smaller. Currently *A. vullgornerensis* is only known from CPV.

Two bones of large sized vultures are present in the sample of CPV, a proximal fragment of a humerus and a distal fragment of a tibiotarsus (Fig. 3 A and B). The fragmentary condition of the material does not permit their accurate identification. We attributed the humerus to cf. *Gyps*, mainly on the basis of the morphology of the *crista deltoidea* and the morphology of the palmar surface, although the morphology of the pneumatic fossa disagrees with our comparison material of *Gyps*. The distal fragment of tibiotarsus belongs to *Aegyptius* sp. The Black Vulture has been tentatively reported in Mallorca from Pedrera de s'Ònix (as *Aegyptius* cf. *monachus*; see Mourer-Chauviré et al., 1977; Alcover et al., 1981). The large-sized Barn Owl *Tyto balearica*, a species also found in Pedrera de s'Ònix (Mourer-Chauviré et al., 1980), is recorded through a complete ulna (Fig. 3 G), and a kestrel-like Falcon *Falco* sp. is represented by two bones (Fig. 3 D-E). The Pleistocene corvid *Pica mourearae*, described from Pedrera de s'Ònix (Seguí, 2001), has also been identified in CPV (Fig. 3 N-P). Another corvid, *Corvus* sp., has been herein identified (Fig. 3 Q-S). Its size, as well as the *Corvus* remains found on other Balearic coeval sites, is smaller than the modern species *Corvus corax*, although it differs in size from *Corvus pliocaenus*.

The avian assemblage obtained in the cave does not allow a global approach to the paleoecology from the Late Pliocene/Early Pleistocene of Mallorca, due to the small size of the sample. Nevertheless, the assemblage fits well with that obtained in Pedrera de s'Ònix, despite the latter being slightly more recent. Excepting *Athene vullgornerensis*, cf. *Gyps*,

Table 1. Bird species present in CPV. The taxa shared by CPV and Pedrera de s'Ònix (PÒ) are indicated. (*) 2 different Anatidae have been obtained from Pedrera de s'Ònix. (**) The species of *Corvus* found in the Pedrera de s'Ònix is *C. pliocaenus*. Two of the obtained bird taxa, *Pica mourearae* and *Athene vullgornerensis*, have never been found outside Mallorca so far, and thus, they should be considered as endemic species to the island.

Taxon	IMEDEA number	Element	Presence in PÒ	Illustration
Anatidae indet.	91889	Right ulna-proximal fragment	X (*)	Fig. 3.H
<i>Aegyptius</i> sp.	91976	Right humerus-condylus lateralis	X	Fig. 3.B
cf. <i>Gyps</i> sp.	94691	Right humerus-proximal fragment	-	Fig. 3.A
<i>Accipiter nisus</i>	91885	Right humerus-proximal fragment	X	Fig. 3.C
<i>Falco</i> sp. (small size)	91884	Right tibiotarsus distal fragment	-	Fig. 3.E
<i>Falco</i> sp. (small size)	91955	Left ulna-distal fragment	-	Fig. 3.D
<i>Crex</i> sp.	91887	Right ulna-distal and medial fragment	-	Fig. 3.I
<i>Scolopax rusticola</i>	91965	Left humerus	X	Fig. 3.J
<i>Columba palumbus</i>	91892	Incomplete left scapula	-	Fig. 3.K
<i>Tyto balearica</i>	90468	Right ulna	X	Fig. 3.G
<i>Athene vullgornerensis</i>	91958	Right tarsometatarsus	-	Fig. 3.F
<i>Athene vullgornerensis</i>	91897	Terminal phalanx	-	
<i>Pica mourearae</i>	91966	Left tarsometatarsus	X	
<i>Pica mourearae</i>	91967	Right tarsometatarsus	X	Fig. 3.P
<i>Pica mourearae</i>	91968	Left tarsometatarsus-distal fragment	X	Fig. 3.O
<i>Pica mourearae</i>	91883	Right carpometacarpus	X	Fig. 3.N
cf. <i>Corvus</i>	91891	Right femur. Juvenile	X (**)	
<i>Corvus</i> sp.	90470	Right humerus	X	Fig. 3.Q
<i>Corvus</i> sp.	90471	Fragmented left tarsometatarsus	X	Fig. 3.S
<i>Corvus</i> sp.	91898	Right carpometacarpus-distal fragment	X	Fig. 3.R
Corvidae indet.	91890	Left tibiotarsus-distal and medial fragment	X	Fig. 3.M
Corvidae indet.	91969	Left coracoid-distal fragment	X	Fig. 3.L
<i>Turdus</i> sp.	91895	Right carpometacarpus	X	
<i>Turdus</i> sp.	90469	Left ulna	X	
Fringillidae indet	91961	Incomplete premaxilla	X	
Fringillidae/Passeridae	91963	Mandible-apical fragment	X	
Passeriformes, indet	91900	Left tarsometatarsus-distal fragment	X	
Passeriformes, indet	91956	Left tarsometatarsus-proximal fragment	X	

Falco sp., *Crex* sp. and *Columba palumbus*, all the taxa recovered in CPV are also present in Pedrera de s'Ònix. The whole fauna fits well with a rocky cliff's avian community in an open shrub environment, with some close water sites.

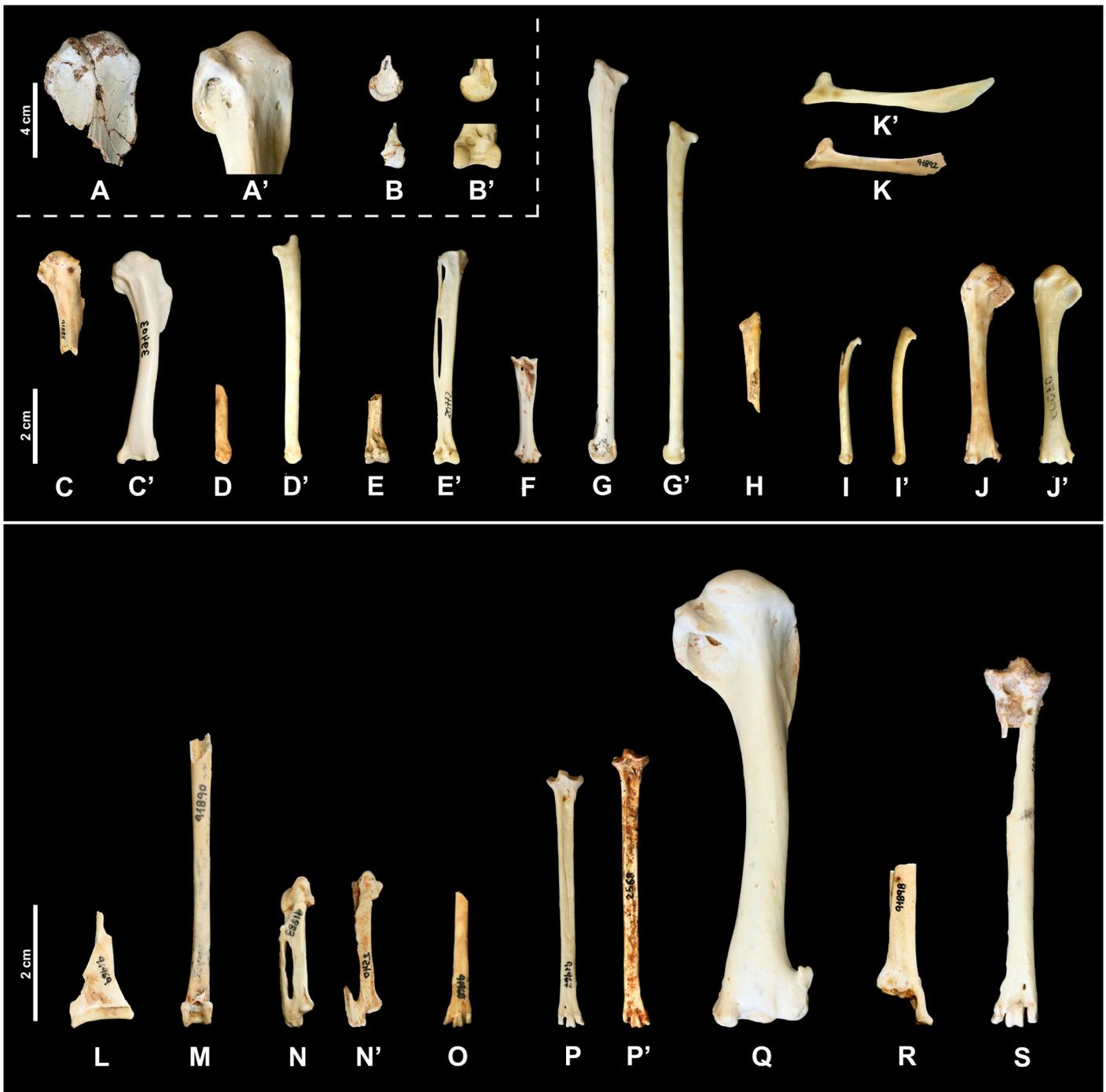


Fig. 3. Bird bones obtained from CPV. Top: Non-Passeriformes from Cova des Pas de Vallgornera (A-K), with comparison material (A'-K'). A: IMEDEA 94691, cf *Gyps*, proximal end of a right humerus, caudal view; A': IMEDEA 60079, *Gyps fulvus*, proximal end of a right humerus, caudal view; B: IMEDEA 91976, *Aegypius* sp., distal end of a left tibiotarsus, medial and cranial views; B': IMEDEA 60145, *Aegypius monachus*, distal end of a left tibiotarsus distal end medial and cranial views; C: IMEDEA 91885, *Accipiter nissus*, proximal end of a right humerus, caudal view; C': IMEDEA 39403, *Accipiter nissus*, proximal end of a left humerus, reversed, caudal view; D: IMEDEA 91955, *Falco* sp., fragmented left ulna, ventral view; D': IMEDEA 20772, *Falco tinnunculus*, left ulna, ventral view; E: IMEDEA 91884, *Falco* sp., distal end of a right tibiotarsus, cranial view; E': IMEDEA 20772, *Falco tinnunculus*, right tibiotarsus, cranial view; F: IMEDEA 91958, *Athene vallgornerensis*, right tarsometatarsus, cranial view; G: IMEDEA 90468, *Tyto balearica*, right ulna, ventral view; G': IMEDEA 21884, *Tyto alba*, right ulna, ventral view; H: IMEDEA 91889, *Anatidae*, undetermined genus and species, proximal part of a left ulna, ventral view; I: IMEDEA 91887, *Crex* sp., fragmented left ulna, ventral view; I': IMEDEA 34882, *Crex crex*, left ulna, ventral view; J: IMEDEA 91965, *Scolopax rusticola*, left humerus, caudal view; J': IMEDEA 60070, *Scolopax rusticola*, reversed right humerus, caudal view; K: IMEDEA 91892, *Columba palumbus*, fragmented left scapula, medial view; K': IMEDEA 20898, *Columba palumbus*, left scapula, medial view. Bottom: Passeriformes from CPV (L-S), together with *Pica moureerae* comparison material (N', P'). L: IMEDEA 91969, Corvidae undetermined genus and species, distal fragment of left coracoid, dorsal view; M: IMEDEA 91890, Corvidae undetermined genus and species, fragmented left tibiotarsus, cranial view; N: IMEDEA 91883, *Pica moureerae*, right carpometacarpus, dorsal view; N': IMEDEA 2540, *Pica moureerae*, reversed left carpometacarpus, dorsal view, Pedrera de s'Ònix, Mallorca; O: IMEDEA 91968, *Pica moureerae*, distal part of a left tarsometatarsus, cranial view; P: IMEDEA 91967, *Pica moureerae*, right tarsometatarsus, cranial view; P': IMEDEA 2568, *Pica moureerae*, right tarsometatarsus, cranial view, Pedrera de s'Ònix, Mallorca; Q: IMEDEA 90470, *Corvus* sp., right humerus, caudal view; R: IMEDEA 91898, *Corvus* sp., distal end of right carpometacarpus, dorsal view; S: IMEDEA 90471, *Corvus* sp., left tarsometatarsus, cranial view.

Mammals

Bones of the three taxa of terrestrial mammals present during all the Late Pliocene to Holocene in Mallorca have been recovered from CPV. Preliminary analysis of the morphological characteristics of these bones (e.g., following Alcover et al., 1981), allows the clear attribution of the obtained material as belonging to *Myotragus*, *Hypnomys* and *Nesiotites*. Thus, the objective of the analysis of the mammalian bones here presented is to identify them to species level. Specifically, the accurate taxonomic attribution of the bones of these three mammalian taxa can furnish an approximate chronological framework to the deposit as the fossil records of these three genera are remarkably complete, especially in the case of *Myotragus*. Additionally, some fossil remains of bats (Chiroptera) have been also obtained from the cave.

Eulipotyphla

Up to 30 bones of *Nesiotites* (Soricidae) have been recovered from CPV (Fig. 4 A). Although postcranial remains of this genus have been recovered, the identification of the different *Nesiotites* species using these bones is ambiguous. For this reason, in order to evaluate the taxonomical attribution of the species found in CPV a Principal Component Analysis (PCA) with tooth and linear measurements of six mandibles of *Nesiotites* from CPV (see Annex 1) and the other species from Mallorca has been performed (four mandibles of *N. ponsi*, six of *N. aff. ponsi* and nine of *N. hidalgo* as comparison material; see Rofes et al., 2012 for further information).

In Fig. 4 B, variables Lm1, TRWm1, TAWm1, Hm1, and Hm2 are included, whereas in Fig. 4.C the variables used are Li, Hi, Lm1, TRWm1, TAWm1, Hm1, Hm2, Lm1-m3, L, H, HC, WC, LUF, and LLF.

Both figures show that on PC1 (indicating the variance in size) the specimens are distributed in three main groups (from left to right): a) Farrutx (*Nesiotites ponsi*, Late Pliocene); b) CPV + Pedrera de s'Ònix (*Nesiotites aff. ponsi*, Early Pleistocene; c) Cova de Llenaire + Cova Estreta + Cova de Canet (*Nesiotites hidalgo*, Late Pleistocene/Holocene). On PC2 (indicating mainly morphology), no clear-cut differentiation can be observed.

The distribution of CPV specimens mainly overlaps with the one of *N. aff. ponsi* from Pedrera de s'Ònix, especially in Fig. 4 C, in which a larger number of variables was obtained. This overlap suggests that the *Nesiotites* from CPV displays a greater affinity with *N. aff. ponsi* than with *N. ponsi* or *N. hidalgo*. Nevertheless, the specimens from Pedrera de s'Ònix are more robust than those from CPV and the coronoid process of the latter specimens lean slightly more lateralwards in posterior view (respect to the mandibular ramus) than those from Pedrera de s'Ònix. Although an unequivocal attribution of the *Nesiotites* from CPV to *N. aff. ponsi* from Pedrera de s'Ònix cannot be established, they share large number of affinities. We identify here the taxa from CPV as *N. aff. ponsi*, although further analyses and material will be necessary to evaluate its presumably close relationships with the Pedrera de s'Ònix *Nesiotites*.

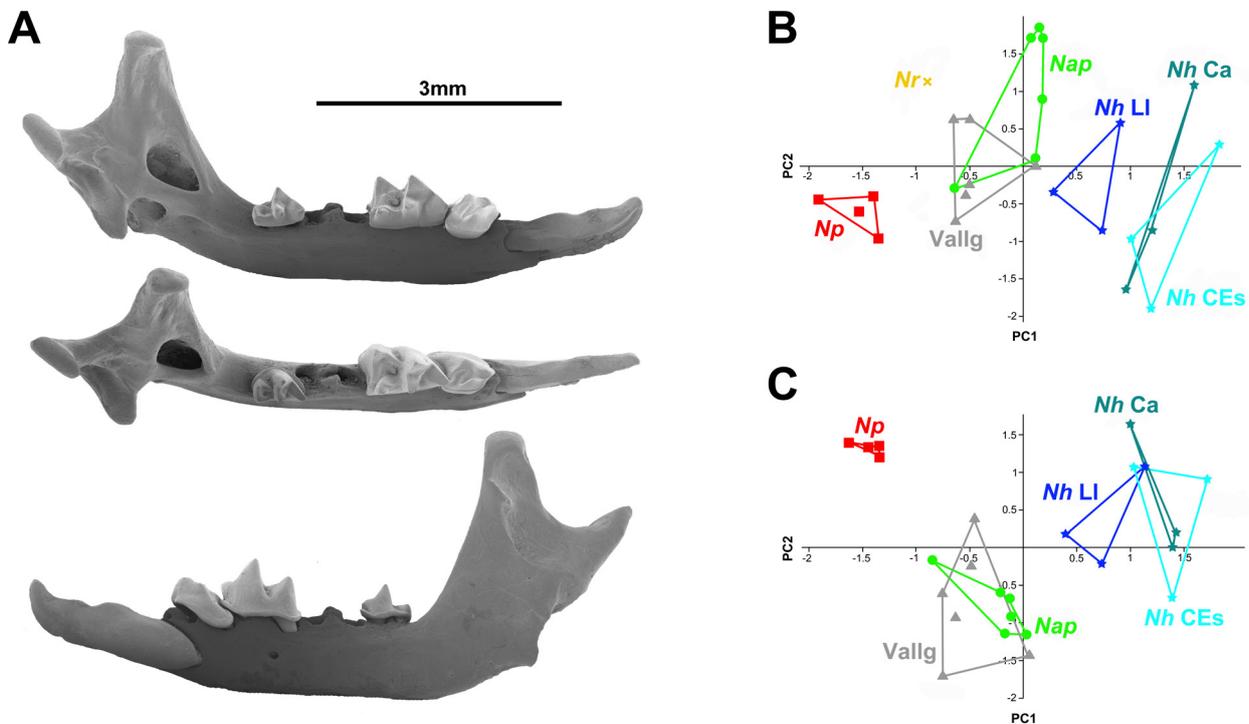


Fig. 4. Analysis of the *Nesiotites* bones found in CPV. A: SEM photo of left mandible IMEDEA 95073, in lingual (top), occlusal (centre), and labial (bottom) views. Principal Component Analysis (PCA) with tooth and linear measurements of mandibles of several species of *Nesiotites* using variables Lm1, TRWm1, TAWm1, Hm1, and Hm2 in B, and variables Li, Hi, Lm1, TRWm1, TAWm1, Hm1, Hm2, Lm1-m3, L, H, HC, WC, LUF, and LLF in C. Abbreviations: Nr, *N. rafelinensis* from Caló den Rafelino. Np, *N. ponsi* from Crulls de Cap Farrutx. Nap, *N. aff. ponsi* from Pedrera de s'Ònix. Nh LI, *N. hidalgo* from Cova de Llenaire, Nh Ca, *N. hidalgo* from Cova de Canet. Nh CEs, *N. hidalgo* from Cova Estreta. Vallg, *Nesiotites aff. ponsi* from CPV.

Rodentia

Up to 483 bones of *Hypnomys* (Gliridae) have been recovered from the Galeria del Tragus/Sala del Col·lapse (Fig. 5 A-I). As in *Nesiotites*, the morphological differences of the postcranial skeleton among the Balearic *Hypnomys* species are small. Nevertheless, we analysed the size of the long limb bones, and teeth.

Additionally to the material obtained in the Galeria del Tragus/Sala del Col·lapse, at least two articulated skeletons and an unarticulated skeleton of *Hypnomys* have been found in different parts of the cave, even in places located far from the former entrance of the cave (Fig. 6 B-D), in Llac de na Gemma, Sector Gregal, and Sector F (Fig. 6 B, C, D, and points 2, 3, 4 in Fig. 1 C, respectively).

No data of measurements of limb bones of the older species of *Hypnomys* have been published and complete specimens of these bones are scarce (personal observation). Mills (1976) published several measurements made on *H. morpheus* long bones. He used long bones lacking one of the epiphyses additionally to complete bones. Thus, the total length of limb bones of *Hypnomys* from CPV has been

compared to those of the scarce complete available material of *H. onicensis* curated at IMEDEA, and to the data published by Mills (1976) and Bover et al. (2010b). The measurements of long limb bones without one of the epiphyses and complete (when available) are furnished in Table 2. Data suggest that no clear distinction among the different species can be established with just postcranial length measurements as the range of measurements of each bone for every species widely overlaps among them.

For this reason, we compared the size of several teeth. As no upper cheek teeth have been obtained in CPV, just data of lower cheek teeth from this cave together with data from bibliography have been used (Reumer, 1979, 1981; Agustí, 1980).

According to Reumer (1981) the ratio width/length of p4 and m3 (Wp4/Lp4 and Wm3/Lm3) seems to discriminate among the different species of *Hypnomys*, and the scatter plot of this ratio also shows the differences in size of the different species. In Fig. 5 J-K, ratios Wp4/Lp4 and Wm3/Lm3 of *Hypnomys* from CPV are compared with the obtained for other *Hypnomys* species by Reumer (1981). Both ratios in

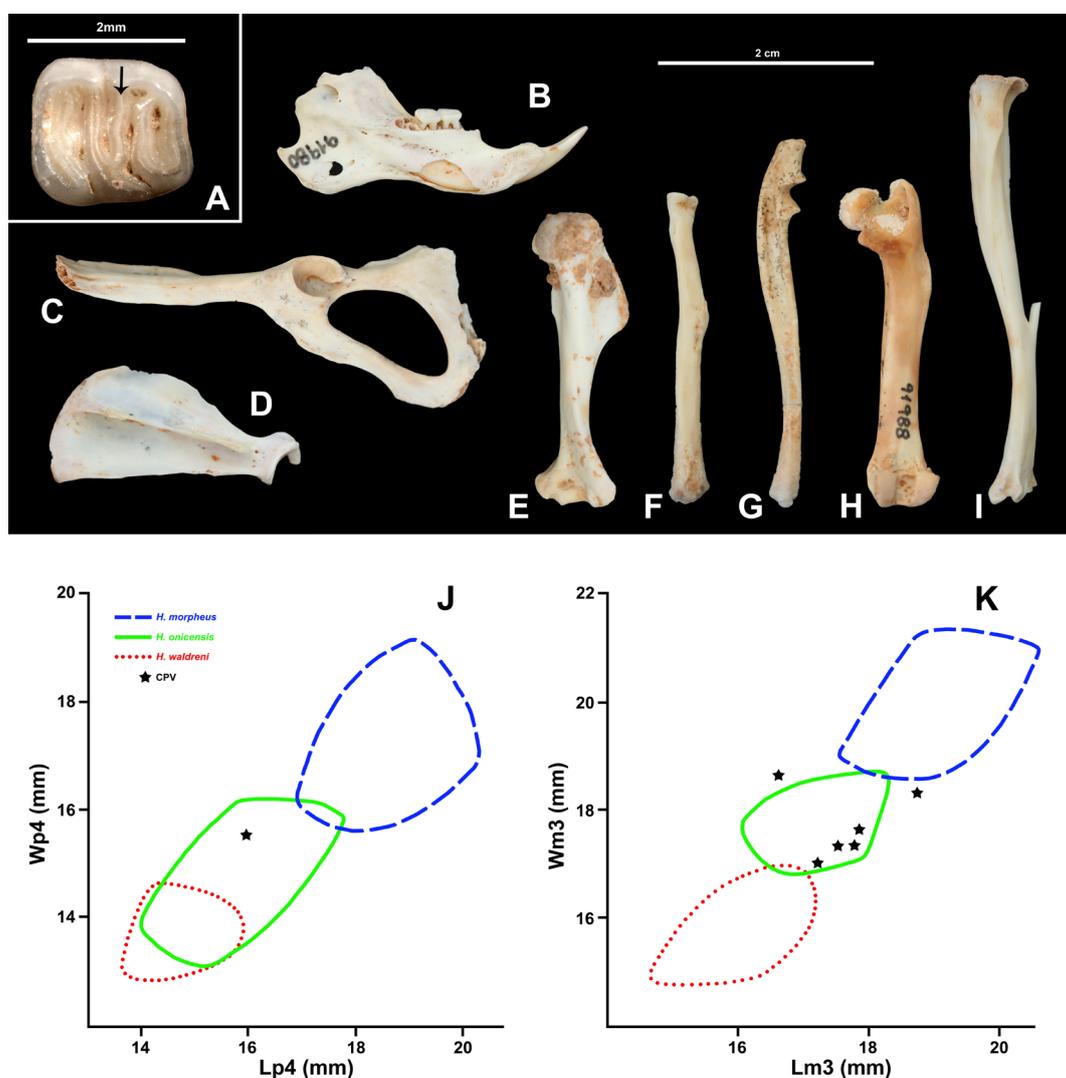


Fig. 5. *Hypnomys* bones from CPV. A: Detail of the right m1 of mandible IMEDEA 95117, occlusal view. The arrow indicates a long centrolophid; B: Left mandible IMEDEA 91980, lingual view; C: Left pelvis IMEDEA 95301, lateral view; D: Right scapula IMEDEA 90467, lateral view; E: Right humerus IMEDEA 95152, caudal view; F: Right radius IMEDEA 91984, cranial view; G: Right ulna IMEDEA 95543, lateral view; H: Right femur IMEDEA 91988, caudal view; I: Right tibia IMEDEA 95136, medial view; J-K: Scatter plot of width versus length of p4 and m3 (modified from Reumer, 1981) of different *Hypnomys* species. New measurements from *Hypnomys* from CPV are plotted with the data for *H. waldreni*, *H. onicensis* from Pedrera de s'Ònix, and *H. morpheus* depicted by Reumer.

Table 2. Mean, range (Max-Min) and number of samples (n) of limb bones length measurements (in mm) using Mills (1976) criteria, for bones without one of the epiphysis (partial bones) and complete bones. Vall. *Hypnomys onicensis*. from CPV; Ho. *H. onicensis* from Pedrera de s'Ònix. Hm. *Hypnomys morpheus* from Cova de Mulet (Measurements for *H. morpheus* recalculated from Mills, 1976) and Cova des Coral-loides (Bover et al., 2010b).

		PARTIAL BONES			COMPLETE BONES		
		HUMERUS			HUMERUS		
		Vall	Ho	Hm	Vall	Ho	Hm
n		8	9	141	3	2	148
Max		24.33	24.95	27.2	27.52	25.37	28.1
Mean		22.57	22.9	23.52	26.3	24.48	23.93
Min		19.54	21.6	21	24.41	23.59	21
		RADIUS			RADIUS		
		Vall	Ho	Hm	Vall	Ho	Hm
n		10	1	47	1	-	12
Max		29.47	-	28.8	-	-	31.2
Mean		27.94	26.26	26.57	29.81	-	29.02
Min		26.47	-	24.1	-	-	24.7
		FEMUR			FEMUR		
		Vall	Ho	Hm	Vall	Ho	Hm
n		10	7	96	2	-	52
Max		34.98	33.17	33.9	34.65	-	36.3
Mean		31.48	31.58	29.79	32.57	-	32.9
Min		28.91	30.53	24.3	30.5	-	28.3
		TIBIA					
		Vall	Ho	Hm			
n		4	3	58			
Max		40.36	39.18	41.2			
Mean		39.4	38.81	38.65			
Min		37.72	38.14	36.2			

the figure indicate that the size and proportions of the studied teeth of CPV *Hypnomys* is included within the variability of *H. onicensis* from Pedrera de s'Ònix, and thus, the rodent remains from CPV can be tentatively attributed to *H. onicensis*.

Agustí (1980) suggested that the presence of a long centrolophid in the m1 and m2 of *H. waldreni* is a primitive characteristic, which is not displayed by the more modern species of *Hypnomys* such as *H. morpheus* and *H. eliomyoides*. As in Pedrera de s'Ònix (see Reumer, 1981), *Hypnomys* from CPV displays long centrolophids in m1 and m2 (Fig. 5.A).

Chiroptera

Two species of fossil bats are present in CPV (Fig. 7). The most abundant is a horseshoe bat (*Rhinolophus*) of middle size, which used the cave as a refuge (Fig. 7 A-D). Currently, three species of middle-sized *Rhinolophus* inhabit the Mediterranean region: *R. mehelyi*, *R. euryale* (both in the named "euryale-group") and



Fig. 6. Associated skeletons found in different places of CPV. A: *Myotragus* sp. in Sector F; B: *Hypnomys* sp. in the Llac de na Gemma; C: *Hypnomys* sp. in Sector de Gregal; D: *Hypnomys* sp. in Sector F. See Fig. 1 for the location of these skeletons in the cave. Photos: A. Merino, M.A. Perelló, G. Mulet and J.A. Alcover.

R. blasii (in the "landeri-group"; Gábor, 2008). The morphology of the skull and humerus of CPV specimen fits well with the species of *euryale* group, and differs from the morphology of *R. blasii*, according to the criteria of Felten et al. (1973), Dodelin (2002), and Lindenau (2005). The shape of the distal epiphysis of the humerus, a highly diagnostic trait for the genus, resembles more to *R. mehelyi* than to *R. euryale*. Nevertheless, the bones measurements are slightly smaller than in recent populations of *R. mehelyi*, and are closer to *R. euryale*. Additionally, about 12 fossil species of *Rhinolophus* have been described in the Western Palearctic (for a summary, see Gunnell et al., 2011). We excluded most of them for comparison, as they are included in the *hipposideros* and *ferrumequinum* groups. *Rhinolophus neglectus* is the sole fossil species of the *euryale* group, and it should be considered as closely related to *R. mehelyi* (Woloszyn, 1987). This group also includes the fossil subspecies *Rhinolophus euryale praeglacialis*. *R. neglectus* and *R. e. praeglacialis* are both insufficiently defined (Popov, 2004). Waiting for a review of the group, CPV horseshoe bat is here attributed to *R. aff. mehelyi*. The second bat species present in the cave is a small *Pipistrellus* represented by two very incomplete specimens (see Fig. 7 E).

Cetartiodactyla

Around 970 bones of *Myotragus* (Bovidae) belonging to a minimum number of 38 individuals have been obtained from our excavation of CPV. They correspond to 894 individual bones, a near complete adult associated skeleton and two partial associate juvenile skeletons. The number of recovered femora is remarkably greater than the number of other limb bones, probably related to an unknown taphonomical reason.

Additionally to the scattered bones in the Galeria del Tragus, an almost complete skeleton of *Myotragus* was found the last day of the excavation in the Sala del Col·lapse at a depth of 10 cm. It was located in a corner of this chamber in anatomical position.

Associated partial skeletons of two *Myotragus* juvenile specimens were found at the beginning of the Galeria del Tragus (Fig. 1 and 2 C). The mandibles of these skeletons display a dp4 completely erupted and m1 near starting the eruption.

Another complete articulated skeleton of *Myotragus* was found far away from the Galeria del Tragus, in the passages of the Sector F (Fig. 6 A, and 1 in Fig. 1 C). This skeleton is covered by flowstone, so the risk of breaking the bones during extraction was extremely high, precluding its excavation. Other *Myotragus* isolated bones, covered with flowstone were found in the biggest chamber of the cave known as Sala Que No Té Nom (Unnamed Hall).

In order to determine the taxonomic identity of the *Myotragus* remains retrieved from the cave, two main characteristics have been observed, both of them related with teeth morphology in adult individuals: first, number and shape of incisors, and second, relative size of the lower and upper premolars (mainly p2-3, P2-3). Although some skulls of *Myotragus* from

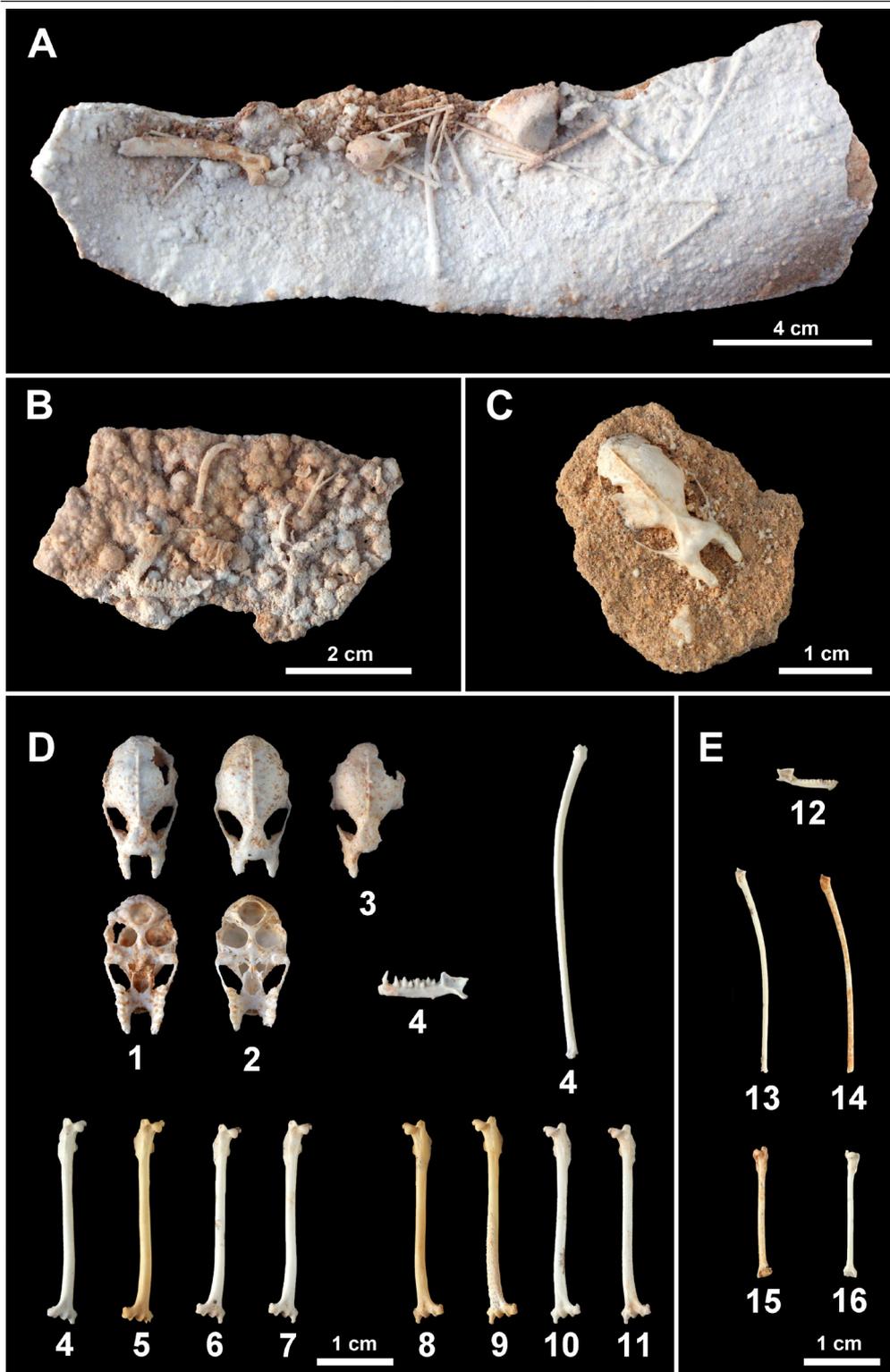


Fig. 7. Bat bones from CPV. A-C: Specimens of *Rhinolophus* aff. *mehelyi* embedded in flowstone. A: IMEDEA 94692, remains of an individual, with a rib of a juvenile *Myotragus*; B: IMEDEA 94693, incomplete specimen, with two jaws, a clavicle and several vertebrae; C: IMEDEA 94694, skull; D: Other specimens of *Rhinolophus* aff. *mehelyi*. 1: IMEDEA 94695 and 2: IMEDEA 94696, skulls, dorsal and ventral views; 3: IMEDEA 94697, skull, dorsal view; 4: IMEDEA 94698, left jaw, labial view; radius, left humerus, posterior view; 5: IMEDEA 94700, 6: IMEDEA 94704, and 7: IMEDEA 94705, left humeri, posterior view; 8: IMEDEA 94699, 9: IMEDEA 94701, 10: IMEDEA 94706, and 11: IMEDEA 94707, right humeri, posterior view; E: Specimens of *Pipistrellus* sp. 12: IMEDEA 94715, right jaw, labial view; 13: IMEDEA 94717 and 14: IMEDEA 94718, radii; 15: IMEDEA 94716 and 16: IMEDEA 94719, humeri, posterior view.

CPV are available, mandibles are more suitable for taxonomical identification and the analysis has been based on this bone.

The number of incisors is a rough indicative of the approximate evolutionary stage of the genus. In this sense, the most recent species, *M. balearicus*, displayed a single evergrowing incisor in each hemimandible (Bate, 1909), while the Early-Late Pliocene species, *M. peygonellae* had four (Moyà-Solà & Pons-Moyà, 1982). No complete mandible with incisors is available for the oldest *Myotragus* species from the Early Pliocene, *M. palomboi* (Bover et al., 2010a). Between *M. peygonellae* and *M. balearicus*, the other taxa of *Myotragus* display a progressive

reduction of the number of incisors, i.e. three in *M. antiquus* (after Pons-Moyà, 1977) and *M. kopperi* (Moyà-Solà & Pons-Moyà, 1981) and two in *M. batei*. Although the holotype of this latter species displays 3 incisors (Crusafont & Angel, 1966), in our view, it represents an incompletely grown specimen and it has been considered that the third small incisor (probably the dI_3 , third deciduous incisor) would be lost later. This same phenomenon has been recorded in some individuals of *M. balearicus* from Late Pleistocene deposits, in which a small distal incisor (or its alveolus) is displayed in juvenile stages, being posteriorly lost in adult ages (see Bover & Alcover, 1999, and references therein).



Fig. 8. Skull and mandibles of the *Myotragus* articulated skeleton (IMEDEA 103003) found in the Sala del Col·lapse. Three incisors can be observed in the mandible (Photo: M.A. Perelló).

Although the shape of the incisors in the different *Myotragus* species can depend on the wear stage of these teeth, the most mesial incisor of the most recent species, *M. batei* and *M. balearicus*, is generally a highly hypsodont evergrowing incisor (i.e., with open root) and very wide mesio-distally. The root of this tooth can be proximally located beyond the diastema, under the premolar series, and can produce a strong deformation of the lingual part of the mandibular body. *M. pepgonellae*, *M. antiquus* and *M. kopperi* display hypsodont incisors, but in a lesser degree than the most recent species, with closed roots and they are not as wide mesiodistally. The basis of the root of the incisors is never located beyond the diastema in the available material of these species.

In the case of the mandibles of *Myotragus* obtained from CPV, all of them display three alveoli for incisors, and the mandibles of the partial skeleton from the Sala des Col·lapse display three incisors each (Fig. 8). Their morphology, especially in the medial incisor, resembles the one of *M. antiquus* and *M. kopperi*, i.e., not extremely hypsodont, and not wide mesiodistally, none of the incisors of the mandibles from CPV extends beyond the diastema, their roots are closed, and the distal incisor (or its alveolus) is greater than the *M. batei* distal incisor (the one that is posteriorly lost in adult stages).

All these observations limit the analysis of the attribution of the CPV *Myotragus* to the species *M. antiquus* or *M. kopperi*. In order to establish a more accurate taxonomy of the CPV *Myotragus*, a further analysis of the mandibles and teeth was performed.

SPECIES	i/c	p2	p3	p4
<i>M. palomboi</i>	4?			
<i>M. pepgonellae</i>	4			
<i>M. antiquus</i>	3			
<i>M. kopperi</i>	3			
<i>M. batei</i>	2			
<i>M. balearicus</i>	1			

] CPV

Fig. 9. Number of incisiforms (i.e., incisors and canine) and lower premolar size in the described *Myotragus* species from Mallorca, in adult stage. Black, present (normal); Dark gray: slightly reduced; Light gray: extremely reduced; White: absent. The specimens from CPV display three incisors and a slightly reduced p3, as *M. kopperi*.

As mentioned above, in the evolution of the *Myotragus* lineage a progressive reduction of size and number of premolars have been identified (Alcover et al., 1981). *M. palomboi*, as other caprines, displayed a slightly reduced p2 (Bover et al., 2010a), and although no other lower premolars for this species are available, it is reasonable to assume that displayed a dentition similar to other mainland caprines (i.e., fully developed premolars). *M. pepgonellae* already displayed an important reduction of the p2, although present (Moyà-Solà & Pons-Moyà, 1982), whereas in *M. antiquus* and *M. kopperi* this teeth is already lost (Pons-Moyà, 1977; Moyà-Solà & Pons-Moyà, 1981). In these two latter species, the p3 is gradually reduced (Fig. 9 and 10 C). *M. batei* displays an extremely reduced p3 (Crusafont & Angel, 1966), and in the more recent species *M. balearicus*, this tooth has completely disappeared (Bate, 1909).

The scatter plots of the proportions of p3 (Lp3/Wp3, Fig. 10 A) and the relative length of this tooth (Ltr/Lp3, Fig. 10 B) suggest that the development of this premolar in the *Myotragus* from CPV falls in the range of variability of *M. kopperi*, especially in the case of Lp3/Wp3. In the case of Ltr/Lp3, the two mandibles measured from CPV show a slightly more developed p3 than *M. kopperi*, but as it happens in this latter species, some individuals display particularly long p3. This characteristic can be observed both in the specimen of *M. kopperi* from Pedrera de s'Ònix IMEDEA 57665 (Fig. 10 C.2), and in the *Myotragus* mandible from CPV IMEDEA 90462 (Fig. 10 C.3), in which the size of p3 is slightly longer than other specimens from the same taxa collected in the same deposits. Nevertheless, these differences could be related to a greater wear of this tooth observed in older individuals, as the p3 is slightly wider and longer in the base of the tooth than in the tip. For all these reasons, the *Myotragus* from CPV is here attributed to *M. aff. kopperi*.

ANCIENT DNA

One sample from CPV (IMEDEA 91480, second upper molar) was used to test for potential contaminating DNA introduced during ancient DNA (aDNA) extraction protocols at the ACAD. The obtained material from CPV was preserved inside the cave from at least 2 My (see below) until the excavation in 2010, free of contamination from other introduced species in Mallorca, and with a putative chronology far beyond the theoretical survival of DNA in ancient samples (e.g., Willerslev & Cooper, 2005). Thus, the sample used was considered to be an adequate negative control for aDNA extractions of *Myotragus balearicus* bones.

The ACAD has a dedicated laboratory on aDNA geographically separated by around 1.5 km from PCR and postPCR laboratories. The extraction method and PCR (Polymerase Chain Reaction) set up parameters have been published elsewhere (e.g., Austin et al., 2013; Brotherton et al., 2013). Briefly, 0.26 g of tooth powder were incubated overnight under constant rotation at 55°C in a lysis buffer of 0.5M EDTA, pH 8.0; 10% SDS; and 20mg/ml proteinase K. DNA

was extracted using a silica-based suspension and and in-house binding buffer method (Brotherton et al., 2013). Universal primers for mammalian mitochondrial DNA 12S gene (Mamm 12S E Forward: 5' CTATAATCGATAAACCCCGATA 3' and Mammal 12S H Reverse: 5' GCTACACCTTGACCTAAC 3', amplifying a fragment of 96 bp, and Mammal 12S N Forward : 5' CAGCAAACCCTAAAAAGG 3' and Mammal 12S H Reverse, see above, amplifying a fragment of 34 bp). These primers were successful in the amplification of *Myotragus balearicus* DNA from Holocene samples as well as contaminating DNA from species as cow (*Bos taurus*), pig (*Sus scrofa*), sheep (*Ovis aries*), goat (*Capra hircus*) and dog (*Canis familiaris*) in other *M. balearicus* samples (pers. obs.).

Two microlitres of extract were used to amplify, together with an extraction control and negative PCR control, in a 25 µl PCR containing: 1 × Platinum

Taq High Fidelity Buffer (Invitrogen), 2 mM MgSO₄, 0.4 µM each primer, 0.25 mM each dNTP, 0.5 U Platinum Taq HiFi (Invitrogen), 1 mg/ml RSA (Sigma-Aldrich) and sterile H₂O. PCR cycling conditions were: initial denaturation at 94°C for 2 min; 50 cycles of denaturation at 94°C for 20 s; primer annealing at 55°C for 15 s; elongation at 68°C for 30 s; a final elongation step at 68°C for 10 min. PCR products were visualized under UV light on a 3.5% agarose gel posteriorly stained with Gel-Red (Jomar Bioscience).

As expected, the PCRs of the CPV sample failed, confirming that the extraction protocol used with the *Myotragus* samples did not introduce detectable amounts of contaminating DNA. The possible sources of DNA contamination detected in some samples should be then related to other agents in the deposits (e.g., soil, or other species living in the same cave, etc.) or even to PCR reagents.

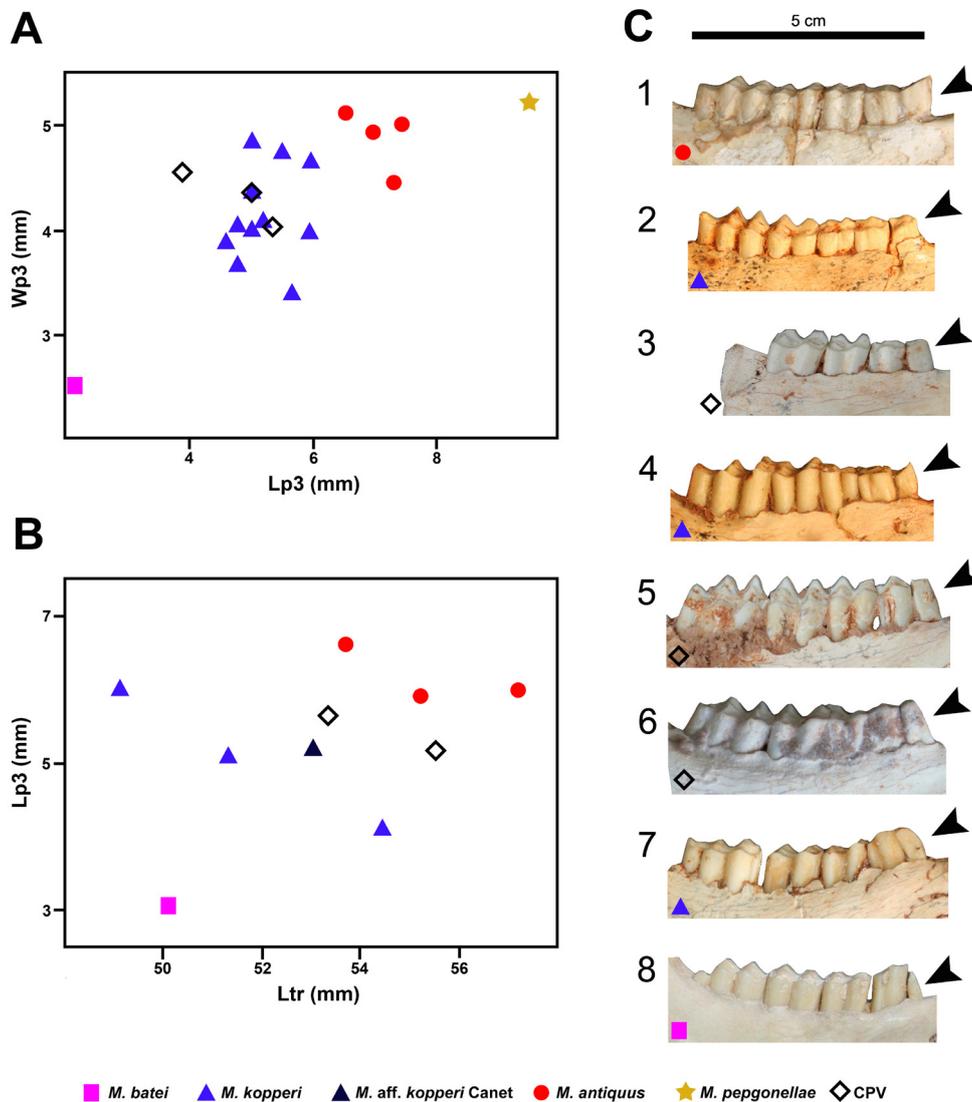


Fig. 10. Scatter plot and comparison of *Myotragus* teeth. A: Scatter plot of width (Wp3) versus length of p3 (Lp3) (measurements taken at 1 cm from the base of the tooth). Data for *M. batei*, *M. kopperi* and *M. antiquus* from Moyà-Solà & Pons-Moyà, 1981. Data for *M. pepgonellae* obtained from Moyà-Solà & Pons-Moyà, 1982. Used specimens from CPV are IMEDEA 90451, 90454 and 103003; B: Scatter plot of length of p3 (Lp3) versus length of tooth row (Ltr) (measurements taken at the base of the tooth). Used specimens from CPV are IMEDEA 90451, 90452 and 90454; C: Labial view of *Myotragus* mandibles to compare the size of the p3 in the different species. 1: *M. antiquus* IMEDEA 59245, left, reversed; 2: *M. kopperi* IMEDEA 57665, right; 3: CPV IMEDEA 90462, left, reversed; 4: *M. kopperi* IMEDEA 57325, right; 5: CPV IMEDEA 90454, left, reversed; 6: CPV IMEDEA 90451, right; 7: *M. kopperi* Holotype IMEDEA 57320, left, reversed; 8: *M. batei* Holotype, curated at MNIB-SHNB, right. Arrows indicate the p3 tooth.

CONCLUSIONS

The similarity of the mammalian taxa from CPV to the species recorded in the Pedrera de s'Ònix deposit sheds some light to the chronology of the deposit and the geomorphic processes involved in the development of the cave. As explained above, *Myotragus* from CPV has a morphotype similar to *M. kopperi*, *Hypnomys* to *H. onicensis* and *Nesiotites* to *N. aff. ponsi* from Pedrera de s'Ònix. Regarding the birds, although there are some differences between these two deposits, up to 14 of the 18 bird taxa identified in CPV were also recorded in the Pedrera de s'Ònix deposit. In Mallorca, the amphibian genus *Discoglossus* has been only found in CPV and in Pedrera de s'Ònix, and the size of the lizard *Podarcis* from CPV agrees with the size of the *Podarcis* remains obtained from Pedrera de s'Ònix. Thus, it seems appropriate to consider CPV as a paleontological deposit from the Early Pleistocene, with a close chronology to Pedrera de s'Ònix.

Paleomagnetic analyses carried out in a Mallorcan cave with a remarkable stratigraphical record, Cova de Canet, furnished a date of 2.6 My for the stratigraphical levels (level J) containing *M. antiquus* and 2.4 My for the level (level E) containing *Myotragus* sp. according to Pons-Moyà et al. (1979), but it was later identified as a morphotype slightly more primitive than the type of *M. kopperi*, and consequently considered *M. aff. kopperi* (Alcover et al., 1981). The ratio Ltr/Lp3 (Fig. 10.B) indicates that the CPV *Myotragus* would be similar to this *M. aff. kopperi* from Cova de Canet. This paleomagnetic data allow us to narrow the deposition period of the fossil material at around 2.4 My ago. In this sense, the absence of more modern species of *Myotragus* in the deposit suggests that the collapse of the original and natural entrance to the cave was a quick event and caused the total sealing of the Galeria del Tragus/Sala del Col·lapse in a moment later than 2.4 My ago, trapping both the bone remains and the living animals that eventually were inside the cave at that moment. The presence of an adult *Myotragus* articulated skeleton (Sala del Col·lapse), and other two associated juvenile skeletons (Galeria del Tragus), agrees with the hypothesis of an original open entrance close to the deposit, and seems to indicate a limited horizontal transport of the bones inside the cave. This observation agrees with the scenario shown by the stratigraphical analysis of the sediments in Galeria des Tragus (Fornós et al., 2010b). In general, the sediment sequence observed at the Galeria del Tragus of CPV is formed by sands and mud-silts that can be considered allochthonous (entrance facies). This characteristic seems to corroborate the existence of an ancient cave entrance through which sand deposits first, and then sediments infiltrated by surface runoff, entered the cave until the likely closing of it after the collapse of this former entry. The absence of clear lamination and flow structures in the sand deposits of aeolian origin suggest a ramp-type deposition favored by gravity. Nevertheless, the sub-horizontal location of these deposits some hundreds of meters along the gallery seems to indicate a deposition of the whole stratigraphic set in a low dynamic aquatic environment.

The finding of some skeletons and other remains of terrestrial mammals in sites located far from the putative former entrance could provide information about other currently closed entrances or fissures. The case of the skeletons of *Hypnomys* in Llac de na Gemma, Sector F, and Sector de Gregal (Fig. 6 B-D) could be explained both by the existence of former entrances or, more probably, small fissures nearby that could be used by this small mammal to entry the cave. More intriguing is the presence of *Myotragus* bones in the Sala Que No Té Nom and specially the case of the articulated skeleton in the upper maze (Fig. 6 A). In several Mallorcan caves, *Myotragus* individuals have been found far away from the current entrance on the cave, indicating that the species was going relatively deep into caves (e.g., Cova des Penyal Blanc; Alcover et al., 1997, or Cova Genovesa; Gràcia et al., 2003). But the important distance from the former entrance, located at the Sala del Col·lapse, and the location of those *Myotragus*, together with the labyrinthine galleries beyond the Galeria del Tragus, seems to indicate the presence of other entrances currently collapsed.

Although an important number of Mallorcan caves containing Pliocene and Quaternary fossils has been already recorded (Bover & Alcover, 2005), the presence of paleontological remains of *Myotragus* is relatively frequent in coastal caves below the current water-table, as the Cova Genovesa (Gràcia et al., 2003) or in air-filled passages, as CPV. In the case of deposits older than Middle Pleistocene, they are mainly hard breccias in fossil caves, and the state of preservation of the bones is usually poor. For this reason, the finding of the fossil material in CPV, with a chronology around 2.4 My, or even older, and in this exceptional preservation state, is outstanding. The material obtained is being currently studied (e.g., Jordana et al., 2013) and it will surely improve our understanding, in a near future, of several aspects of the taxonomy, evolution and morphology of the species found in CPV.

The geochronological data supplied by the paleontologic deposit from Galeria del Tragus is quite determinant regarding the minimum age of speleogenesis that could be postulated for CPV (Ginés et al., 2014). In this respect, the main cave-formation phases must correspond at least to mid-Pliocene times, with a later sea-controlled complex evolution happened along the whole Quaternary.

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REFERENCES

Agustí J., 1980 - *Hypnomys eliomyoides nov. sp. nuevo glírido (Rodentia, Mammalia) del Pleistoceno de Menorca*. Endins, **7**: 49-52.

- Agustí J., Bover P. & Alcover J.A., 2012 - *A new genus of endemic cricetid (Mammalia, Rodentia) from the late Neogene of Mallorca (Balearic Islands, Spain)*. Journal of Vertebrate Paleontology, **32**: 722-726.
<http://dx.doi.org/10.1080/02724634.2012.652322>
- Alcover J.A., Moyà-Solà S. & Pons-Moyà J., 1981 - *Les Quimeres del Passat. Els Vertebrats Fòssils del Plioceno-Quaternari de les Balears i Pitiüses*. Monografies Científiques, Editorial Moll, Palma, 260 p.
- Alcover J.A., Font A. & Trias M., 1997 - *Primera troballa de fauna vertebrada pliocènica a Cabrera*. Endins, **21**: 79-82.
- Alcover J.A., Díaz A. & Bover P., 2014 - *Fossil vertebrate database from Cova des Pas de Vallgornera (Llucmajor, Mallorca)*. International Journal of Speleology, **43** (2): xxx-xxx.
<http://dx.doi.org/10.5038/1827-806X.43.2.TBD>
- Austin J., Soubrier J., Prevosti F.J., Prates L., Trejo V., Mena F. & Cooper A., 2013 - *The origins of the enigmatic Falkland Islands wolf*. Nature Communications, **4**: 1552. <http://dx.doi.org/10.1038/ncomms2570>
- Bailon S., Bover P., Quintana J. & Alcover J.A., 2010 - *First fossil record of *Vipera Laurenti* 1768 “Oriental vipers complex” (Serpentes: Viperidae) from the Early Pliocene of the Western Mediterranean Islands*. Comptes Rendus Palevol, **9**: 147-154.
<http://dx.doi.org/10.1016/j.crpv.2010.04.001>
- Bailon S., Boistel R., Bover P. & Alcover J.A., 2014 - *Maioricalacerta rafelinensis gen. et sp. nov (Squamata, Lacertidae) from the Early Pliocene of Mallorca (Balearic Islands, Western Mediterranean Sea)*. Journal of Vertebrate Paleontology, **34** (2): 318-326.
- Bate D.M.A., 1909 - *Preliminary note on a new artiodactyle from Mallorca *Myotragus balearicus*, gen. et sp. nov.* Geological Magazine, **6**: 385-389.
<http://dx.doi.org/10.1017/S0016756800124665>
- Bate D.M.A., 1918 - *On a new genus of extinct muscardine rodent from the Balearic Islands*. Proceedings of the Zoological Society London, **88**: 209-222
<http://dx.doi.org/10.1111/j.1096-3642.1918.tb02091.x>
- Bate D.M.A., 1944 - *Pleistocene shrews from the larger Western Mediterranean Islands*. The Annals and Magazine of the Natural History Series, **11**: 738-769.
- Bover P. & Alcover J.A., 1999 - *The evolution and ontogeny of the dentition of *Myotragus balearicus* Bate 1909 (Artiodactyla: Caprinae): evidences from new fossil data*. Biological Journal of the Linnean Society, **68**: 401-428.
<http://dx.doi.org/10.1111/j.1095-8312.1999.tb01178.x>
- Bover P. & Alcover J.A., 2005 - *Catàleg de jaciments amb *Myotragus a les Illes Balears**. In: Alcover J.A. & Bover P. (Eds.), *Proceedings of the International Symposium “Insular Vertebrate Evolution: the Palaeontological Approach”*. Monografies de la Societat d’Història Natural de les Balears, **12**: 51-58.
- Bover P. & Tolosa F., 2005 - *The olfactory ability of *Myotragus balearicus*: preliminary notes*. In: Alcover J.A. & Bover P. (Eds.), *Proceedings of the International Symposium “Insular Vertebrate Evolution: the Palaeontological Approach”*. Monografies de la Societat d’Història Natural de les Balears, **12**: 85-94.
- Bover P., Quintana J., Agustí J., Bailón S. & Alcover J.A., 2007 - *Caló den Rafelino: an Early Pliocene site in Mallorca, Western Mediterranean*. In: - *Abstracts del “VII Simposio Internacional de Zoología”*. Topes de Collantes: 119.
- Bover P., Quintana J. & Alcover J.A., 2008 - *Three islands, three worlds: paleogeography and evolution of the vertebrate fauna from the Balearic Islands*. Quaternary International, **182**: 135-144.
<http://dx.doi.org/10.1016/j.quaint.2007.06.039>

- Bover P., Quintana J. & Alcover J.A., 2010a - *A new species of Myotragus Bate, 1909 (Artyodactyla, Caprinae) from the Early Pliocene of Mallorca (Balearic Islands, western Mediterranean)*. Geological Magazine, **147**: 871-885. <http://dx.doi.org/10.1017/S0016756810000336>
- Bover P., Alcover J.A., Michaux J.J., Hautier L. & Hutterer R., 2010b - *Body shape and life style of the extinct Balearic dormouse Hypnomys (Rodentia, Gliridae): new evidence from the study of associated skeletons*. PLoS ONE, **5** (12): e15817. <http://dx.doi.org/10.1371/journal.pone.0015817>
- Bover P., Rofes J., Bailon S., Agustí J., Cuenca-Bescós G., Torres E. & Alcover J.A., 2014 - *Late Miocene/Early Pliocene vertebrate fauna from Mallorca (Balearic Islands, Western Mediterranean): an update*. Integrative Zoology, **9**: 183-196. <http://dx.doi.org/10.1111/1749-4877.12049>
- Brotherton P., Haak W., Templeton J., Brandt G., Soubrier J., Adler C.J., Richards S.M., Der Sarkissian C., Ganslmeier R., Friederich S., Dresely V., vanOven M., Kenyon R., Van der Hoek M.B., Koriach J., Luong K., Ho S.W.Y., Quintana-Murci L., Behar D.M., Meller H., Alt K.W., Cooper A. & The Genographic Consortium., 2013 - *Neolithic mitochondrial haplogroup H genomes and the genetic origins of Europeans*. Nature Communications, **4**: Art.1764. <http://dx.doi.org/10.1038/ncomms2656>
- Clauzon G., Suc J.P., Gautier F., Berger A. & Loutre M.F., 1996 - *Alternate interpretation of the Messinian salinity crisis: controversy resolved?* Geology, **24**: 363-366. [http://dx.doi.org/10.1130/0091-7613\(1996\)024<0363:AIOTMS>2.3.CO;2](http://dx.doi.org/10.1130/0091-7613(1996)024<0363:AIOTMS>2.3.CO;2)
- Collignon M., 1982 - *Une première des espéleós namurois à Majorque (Espagne)*. Au royaume d'Hades, **2**: 14-26.
- Crusafont M. & Angel B., 1966 - *Un Myotragus (Mammifère Ruminant), dans le Villafranchien de l'île de Majorque: Myotragus batei, nov. sp.* Comptes Rendues de l'Académie de Sciences Paris, **262**: 2012-2014.
- Dodelin B., 2002 - *Identification des Chiroptères de France à partir des restes osseux*. Fédération Française de Spéléologie, La Ravoire, 48 p.
- Dorale J.A., Onac B.P., Fornós J.J., Ginés J., Ginés A., Tuccimei P. & Peate D.W., 2010 - *Sea-level highstand 81,000 years ago in Mallorca*. Science, **327**: 860-863. <http://dx.doi.org/10.1126/science.1181725>
- Encinas J.A., 2006 - *Relación inventarial de subterráneos naturales de las Illes Balears, año 2006*. Ediciones JAES, Colección Tarsilbet, Pollença, 236p.
- Encinas J.A. & Alcover J.A., 1997 - *El jaciment fòssilífer de la Cova Estreta (Pollença)*. Endins, **21**: 83-92.
- Felten H., Helfricht A. & Storch G., 1973 - *Die Bestimmung der Europäischen Fledermäuse nach der distalen Epiphyse des Humerus*. Senckenbergiana biol., **54**: 291-297.
- Fornós J.J. & Gelabert B., 2004 - *Baleares*. In: Vera J.A. (Ed.), *Geología de España*. Madrid: Sociedad Geológica de España, Instituto Geológico y Minero de España: 450-464.
- Fornós J.J., Pomar L. & Ramos E., 2002 - *Tertiary: Balearic Islands*. In: Gibbons W. & Moreno T. (Eds.), *The Geology of Spain*. Geological Society of London: 327-334.
- Fornós J.J., Ginés A., Ginés J., Gràcia F., Merino A., Cifre J. & Hierro F., 2010a - *Hypogene speleogenetic evidences in the development of Cova des Pas de Vallgornera (Mallorca Island, western Mediterranean)*. In: Andreo B., Carrasco F., Durán J.J. & Lamoreaux J.W. (Eds.), *Advances in research in karst media*. Berlin: Environmental Earth Sciences Series Springer-Verlag: 349-354. http://dx.doi.org/10.1007/978-3-642-12486-0_54
- Fornós J.J., Ginés J., Merino A. & Bover P., 2010b - *El rebliment sedimentari de la galeria del Tragus a la cova des Pas de Vallgornera (Llucmajor, Mallorca)*. Bolletí de la Societat d'Història Natural de les Balears, **53**: 179-192.
- Fornós J.J., Merino A., Ginés J., Ginés A. & Gràcia F., 2011 - *Solutional features and cave deposits related to hypogene speleogenetic processes in a littoral cave of Mallorca Island (western Mediterranean)*. Carbonates and Evaporites, **26**: 69-81. <http://dx.doi.org/10.1007/s13146-010-0040-3>
- Fornós J.J., Ginés J., Gràcia F., Merino A., Gómez-Pujol L. & Bover P., 2014 - *Cave deposits and sedimentary processes in Cova des Pas de Vallgornera (Mallorca, Western Mediterranean)*. International Journal of Speleology, **43** (2): 159-174. <http://dx.doi.org/10.5038/1827-806X.43.2.5>
- Furió M. & Pons-Monjo G., 2013 - *The use of the species concept in paleontology. Comment on "Nesiotites rafelinensis sp. nov., the earliest shrew (Mammalia, Soricidae) from the Balearic Islands, Spain" by Rofes et al., 2012*. Palaeontologia Electronica, **16**: 16A.
- Gábor C., 2008 - *Taxonomy of the Horseshoe Bats of the World (Chiroptera, Rhinolophidae)*. PhD Dissertation, University of Debrecen, Hungary: 178 p.
- Gautier F., Clauzon G., Suc J.P., Cravatte J. & Violantini D., 1994 - *Âge et durée de la crise de salinité messinienne*. Comptes Rendus de l'Académie des Sciences Naturelles de Paris, Serie II, **318**: 1103-1109.
- Gibbard P.L., Head M.J., Walker M.J.C. & The Subcommission on Quaternary Stratigraphy., 2010 - *Formal ratification of the Quaternary System/Period and the Pleistocene Series/Epoch with a base at 2.58 Ma*. Journal of Quaternary Science, **25**: 96-102. <http://dx.doi.org/10.1002/jqs.1338>
- Ginés J., Ginés A., Fornós J.J., Gràcia F. & Merino A., 2008 - *Noves observacions sobre l'espeleogènesi en el Migjorn de Mallorca: els condicionants litològics en alguns grans sistemes subterranis litorals*. Endins, **32**: 49-79.
- Ginés J., Ginés A., Fornós J.J., Merino A. & Gràcia F., 2009a - *On the role of hypogene speleogenesis in shaping the coastal endokarst of southern Mallorca (western Mediterranean)*. In: Klimchouk A.B. & Ford D.C. (Eds.), *Hypogene speleogenesis and karst hydrogeology of artesian basins. Special paper 1*. Simferopol: Ukrainian Institute of Speleology and Karstology: 91-99.
- Ginés J., Ginés A., Fornós J.J., Merino A. & Gràcia F., 2009b - *About the genesis of an exceptional coastal cave from Mallorca island (Western Mediterranean). The lithological control over the pattern and morphology of Cova des Pas de Vallgornera*. In: White W.B. (Ed.), *Proceedings of the 15th International Congress of Speleology*. Kerrville: International Union of Speleology: (1) 481-487.
- Ginés J., Fornós J.J., Ginés A., Merino A. & Gràcia F., 2014 - *Geologic constraints and speleogenesis of Cova des Pas de Vallgornera, a complex coastal cave from Mallorca Island (Western Mediterranean)*. International Journal of Speleology, **43** (2): 105-124. <http://dx.doi.org/10.5038/1827-806X.43.2.2>
- Gràcia F., Jaume D., Ramis D., Fornós J.J., Bover P., Clamor B., Gual M.A. & Vadell M., 2003 - *Les coves de Cala Anguila (Manacor, Mallorca). II: la cova Genovesa o cova d'en Bessó. Espeleogènesi, geomorfologia, hidrologia, sedimentologia, fauna, paleontologia, arqueologia i conservació*. Endins, **25**: 43-86.
- Gràcia F., Fornós J.J., Gamundi P., Clamor B., Pocoví J. & Perelló M.A., 2009 - *Les descobertes subaquàtiques a la Cova des Pas de Vallgornera (Llucmajor, Mallorca): història i descripció dels descobriments, hidrologia, espeleotemes, sediments, paleontologia i fauna*. Endins, **33**: 35-72.

- Guerra C., Bover P. & Alcover J.A., 2012 - *A new species of extinct little owl from the Pleistocene of Mallorca (Balearic Islands)*. Journal of Ornithology, **152**: 347-354. <http://dx.doi.org/10.1007/s10336-011-0749-3>
- Gunnell G.F., Eiting T.P. & Geraads D., 2011 - *New late Pliocene bats (Chiroptera) from Ahl al Oughlam, Morocco*. Neues Jahrbuch für Geologie und Paläontologie, **260**: 55-71. <http://dx.doi.org/10.1127/0077-7749/2011/0128>
- Hammer Ø., Harper D.A.T. & Ryan P.D., 2001 - *PAST: Paleontological Statistics Software Package for Education and Data Analysis. Version 2.01*. Palaeontologia Electronica, **4**: art.4, 9pp.
- Jordana X. & Köhler M., 2011 - *Enamel microstructure in the fossil bovid Myotragus balearicus (Majorca, Spain): implications for life-history evolution of dwarf mammals in insular ecosystems*. Palaeogeography, Palaeoclimatology, Palaeoecology, **300**: 59-66. <http://dx.doi.org/10.1016/j.palaeo.2010.12.008>
- Jordana X., Marín-Moratalla N., Moncunill-Solé B., Bover P., Alcover J.A. & Köhler M., 2013 - *First fossil evidence for the advance of replacement teeth coupled with life history evolution along an anagenetic mammalian lineage*. PLoS ONE, **8**: e70743. <http://dx.doi.org/10.1371/journal.pone.0070743>
- Köhler M. & Moyà-Solà S., 2004 - *Reduction of brain and sense organs in the fossil insular bovid Myotragus*. Brain, Behavior and Evolution, **63**: 125-140. <http://dx.doi.org/10.1159/000076239>
- Köhler M. & Moyà-Solà S., 2009 - *Physiological and life history strategies of a fossil large mammal in a resource-limited environment*. Proceedings of the National Academy of Science USA, **106**: 20354-20358. <http://dx.doi.org/10.1073/pnas.0813385106>
- Kotsakis T., 1981 - *Le Lucertole (Lacertidae, Squamata) del Pliocene, Pleistocene e Olocene delle Baleari*. Bolletti de la Societat d'Història Natural de les Balears, **25**: 135-150.
- Krijgsman W., Hilgen F.J., Raffi I., Sierro F.J. & Wilson D.S., 1999 - *Chronology, causes and progression of the Messinian salinity crisis*. Nature, **400**: 652-655. <http://dx.doi.org/10.1038/23231>
- Lindenau C., 2005 - *Middle Pleistocene bats (Mammalia: Chiroptera) from the Yarimburgaz Cave in Turkish Thrace (Turkey)*. Eiszeitalter und Gegenwart, **55**: 122-148.
- Merino A., 1993 - *La Cova des Pas de Vallgornera*. Endins, **19**: 17-23.
- Merino A., 2000 - *Nuevas extensiones de la Cova des Pas de Vallgornera (Llucmajor, Mallorca)*. Endins, **23**: 7-21.
- Merino A. & Fornós J.J., 2010 - *Los conjuntos morfológicos de flujo ascendente (morphologic suite of rising flow) en la Cova des Pas de Vallgornera (Llucmajor, Mallorca)*. Endins, **34**: 85-100.
- Merino A., Mulet A. & Mulet G., 2006 - *La cova des Pas de Vallgornera: 23 kilòmetros de desarrollo topografiado (Llucmajor, Mallorca)*. Endins, **30**: 29-48.
- Merino A., Mulet A., Mulet G., Croix A. & Gràcia F., 2007 - *La cova des Pas de Vallgornera (Llucmajor, Mallorca): 40 kilòmetros de desarrollo topografiado*. Endins, **31**: 101-110.
- Merino A., Mulet A., Mulet G., Croix A. & Gràcia F., 2008 - *La cova des Pas de Vallgornera (Llucmajor, Mallorca): alcanza los 55 kilòmetros de desarrollo topográfico*. Endins, **32**: 33-42.
- Merino A., Mulet A., Mulet G., Croix A. & Gràcia F., 2009 - *Cova des Pas de Vallgornera: an exceptional littoral cave from Mallorca island (Spain)*. In: White W.B. (Ed.), *Proceedings of the 15th International Congress of Speleology*. Kerrville: International Union of Speleology: (**1**) 522-527.
- Merino A., Mulet A., Mulet G., Croix A., Kristofersson A., Gràcia F., Ginés J. & Fornós J.J., 2011 - *La cova des Pas de Vallgornera (Llucmajor, Mallorca). La cavitat de major desenvolupament de les Illes Balears*. Endins, **35**/Monografies de la Societat d'Història Natural de les Balears, **17**: 147-164.
- Merino A., Mulet A., Mulet G., Croix A., Kristofersson A., Gràcia F. & Perelló M.A., 2014 - *Cova des Pas de Vallgornera, (Mallorca, Spain): history of exploration and cave description*. International Journal of Speleology, **43** (2): 95-104. <http://dx.doi.org/10.5038/1827-806X.43.2.1>
- Mills D.H., 1976 - *Osteological study of the Pleistocene dormouse Hypnomys morpheus Bate from Mallorca (Rodentia, Gliridae)*. Publications from the Palaeontological Institution of the University of Uppsala, Special Volume, **4**: 1-58.
- Mourer-Chauviré C., Moyà-Solà S. & Adrover R., 1977 - *Les oiseaux des gisements quaternaires de Majorque*. Nouvelles Archives du Muséum d'Histoire Naturelle de Lyon, **15**: 61-64.
- Mourer-Chauviré C., Alcover J.A., Moyà-Solà S. & Pons-Moyà J., 1980 - *Une nouvelle forme insulaire d'effraie géante, Tyto balearica n. sp., (Aves, Strigiformes), du Plio-Pléistocene des Baléares*. Geobios, **13**: 803-811. [http://dx.doi.org/10.1016/S0016-6995\(80\)80060-X](http://dx.doi.org/10.1016/S0016-6995(80)80060-X)
- Moyà-Solà S. & Pons-Moyà J., 1981 - *Myotragus kopperi, une nouvelle espèce de Myotragus Bate, 1909 (Mammalia, Artiodactyla, Rupicaprini)*. Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Ser. B, **84**: 57-6.
- Moyà-Solà S. & Pons-Moyà J., 1982 - *Myotragus peponellae nov. sp. un primitivo representante del género Myotragus Bate, 1909 (Bovidae, Mammalia) en la isla de Mallorca (Balears)*. Acta Geológica Hispánica, **17**: 77-87.
- Pomar L., Ward W.C. & Green D.G., 1996 - *Upper Miocene reef complex of the Llucmajor area, Mallorca, Spain*. In: Franseen E., Esteban M., Ward W.C. & Rouchy J.M. (Eds.), *Models for carbonate stratigraphy from Miocene reef complexes of the Mediterranean regions*. SEPM Concepts in Sedimentology and Paleontology, **5**: 191-225.
- Pons-Monjo G., Furió M. & Moyà-Solà S., 2010 - *The genus Nesiotites (Soricidae, Insectivora, Mammalia) in the Balearic Islands: state of the art*. Cidarís, **30**: 253-258.
- Pons-Monjo G., Moyà-Solà S. & Furió M., 2012 - *New data on the origin of Nesiotites (Soricidae, Mammalia) in Menorca (Balearic Islands, Spain)*. Comptes Rendus Palevol, **11**: 393-401. <http://dx.doi.org/10.1016/j.crpv.2012.03.001>
- Pons-Moyà J., 1977 - *La nouvelle espèce Myotragus antiquus de l'île de Majorque (Baléares)*. Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Ser. B, **80**: 215-221.
- Pons-Moyà J. & Moyà-Solà S., 1980 - *Nuevo representante del género Nesiotites Bate, 1944; Nesiotites meloussae nov. sp. (Insectivora. Soricidae) de los relleños cársticos del Barranc de Binigaus (Es Mercadal, Menorca)*. Endins, **7**: 53-56.
- Pons-Moyà J., Moyà-Solà S. & Kopper S., 1979 - *La fauna de mamíferos de Sa Cova de Canet y su cronología*. Endins, **5-6**: 55-58.
- Popov V., 2004 - *Pliocene small mammals (Mammalia, Lipotyphla, Chiroptera, Lagomorpha, Rodentia) from Muselievo (North Bulgaria)*. Geodiversitas, **26**: 403-491.
- Quintana J., Bover P., Alcover J.A., Agustí J. & Bailon S., 2010 - *Presence of Hypolagus Dice, 1917 (Mammalia, Lagomorpha) in the Neogene of the Balearic Islands (Western Mediterranean): Description of Hypolagus balearicus nov. sp.* Geobios, **43**: 555-567. <http://dx.doi.org/10.1016/j.geobios.2010.03.003>
- Rabeder G., 1972 - *Die Insectivoren und Chiropteren (Mammalia) aus dem Altpleistozän von Hundshheim (Niederösterreich)*. Annalen des Naturhistorischen Museums in Wien, **76**: 375-474.

- Reumer J.W.F., 1979 - *On two new micromammals from the Pleistocene of Mallorca*. Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Ser. B, **82**: 473-482.
- Reumer, J.W.F., 1980 - *On the Pleistocene shrew Nesiotites hidalgo Bate 1944 from Majorca (Insectivora, Soricidae)*. I & II. Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Ser. B, **83**: 39-68.
- Reumer J.W.F., 1981 - *The Pleistocene mammals from Sa Pedrera de S'Onix, Majorca (Gliridae, Soricidae)*. Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Ser. B, **84**: 2-11.
- Reumer J.W.F., 1984 - *Ruscinian and Early Pleistocene Soricidae*. Geological Survey Professional Paper, **565**: 1-74.
- Reumer J.W.F., 1994 - *Eliomys (Hypnomys) onicensis nomen novum, to replace the homonym Hypnomys intermedius Reumer, 1981 (Rodentia: Gliridae) from Majorca*. Zeitschrift für Säugetierkunde, **59**: 380-381.
- Rofes J., Bover P., Cuenca-Bescós G. & Alcover J.A., 2012 - *Nesiotites rafelinensis sp. nov., the earliest shrew (Mammalia, Soricidae) from the Balearic Islands, Spain*. Palaeontologia Electronica, **15**: 8A.
- Rofes J., Bover P., Cuenca-Bescós G. & Alcover J.A., 2013 - *Proportions, characters and chronologies: their contribution to systematic paleontology. A rebuttal to Furió and Pons-Monjo*. Palaeontologia Electronica, **16** (2): 20A.
- Seguí B., 2001 - *A new species of Pica (Aves: Corvidae) from the Plio-Pleistocene of Mallorca, Balearic Islands (Western Mediterranean)*. Geobios, **34**: 339-347. [http://dx.doi.org/10.1016/S0016-6995\(01\)80080-2](http://dx.doi.org/10.1016/S0016-6995(01)80080-2)
- Sondaar P.Y., McMinn M., Seguí B. & Alcover J.A., 1995 - *Interès paleontològic dels jaciments càrstics de les Gimnèsies i les Pitiüses*. Endins, **20**/Monografies de la Societat d'Història Natural de les Balears, **3**: 155-170.
- Tuccimei P., Soligo M., Fornós J.J., Ginés A., Ginés J., Onac B.P. & Villa I.M., 2009 - *Precipitation of phreatic overgrowths at the water table of meteoric-marine mixing zones in coastal cave systems: a useful tool in sea level change reconstruction*. In: White W.B. (Ed.), *Proceedings of the 15th International Congress of Speleology*. Kerrville: International Union of Speleology: **(1)** 554-560.
- Willerslev E. & Cooper A., 2005 - *Ancient DNA*. Proceedings of the Royal Society B, **272**: 3-16. <http://dx.doi.org/10.1098/rspb.2004.2813>
- Woloszyn B.W., 1987 - *Pliocene and Pleistocene bats of Poland*. Acta Palaeontologica Polonica, **32**: 207-325.